Digital Image Watermarking Techniques Using Machine Learning

A Thesis Report submitted in fulfillment of the requirement

for the award of the degree of

Master of Technology

In

Computer Science & Engineering

Under the Supervision of

Dr. Pardeep Kumar

(Supervisor)

Dr. Amit Kumar Singh

(Co-Supervisor)

by

(Swati Sharma, 142207)

Jaypee University of Information Technology,Waknaghat, Solan, Himachal Pradesh-India 173234

Certificate

This is to certify that thesis report entitled **"Digital Image Watermarking Techniques Using Machine Learning"**, submitted by **Swati Sharma** in fulfillment for the award of degree of Master of Technology in Computer Science & Engineering to Jaypee University of Information Technology,Waknaghat,Solan has been made under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

Supervisor's Name -Dr.Pardeep Kumar

Dated:

Signature

Co-Supervisor's Name - Dr. Amit Kumar Singh

Dated:

Signature

Acknowledgement

I would like to take this opportunity to acknowledge all those who helped me during this report work. Compiling a year's work into this was an exhausting job, but writing this page of acknowledgement is a joyous task to cherish the memories of all those who helped me to enrich the newer experience of life.

At the very onset, I bow my head with reverence and dedicatedly accord my recondite and gratitude to "ALMIGHTY", the merciful and compassionate, whose grace, glory and blessings allowed me to complete this endeavor and without his encouragement and co-operation it would have never been possible for me to achieve this.

I owe my deep sense of respect and heart felt gratitude to my major supervisor ***Dr. Pardeep Kumar, Assistant Professor, Computer Science and Engineering Department, Jaypee University of Information Technology*** for his meticulous and sagacious guidance, sympathetic encouragement, precise and constructive criticism and ever willing help throughout the course of this investigation as well as in the preparation of manuscript. I will always remain indebted to him for his unending guidance and untiring efforts in successful completion of this work. I consider myself fortunate to have worked under his able guidance.

I am highly obliged and grateful to co-supervisor, ***Dr. Amit Kumar Singh, Assistant Professor, Computer Science and Engineering Department, Jaypee University of Information Technology*** for his valuable suggestion sand co-operation throughoutmy research work. I express my sincere and whole hearted thanks to him for rendering help and moral support.

I am thankful to office staff of the department for providing all the necessary and timely help. I am also thankful to respondents of my study for their co-operation who helped me to complete my study.

I wish to express my sincere thanks to all my friends for their support and guidance. There is paucity of words to express my heartiest thank to my friends **Ms. Aditi Zear** and ***Ms KshitizaVasudeva*** for their timely help, best wishes and cheerful company remained a morale booster and made things smother throughout the course of this study.

I owe my achievements to the unconditional love and support of my parents whose sacrifice I can never repay. They inspired me at every step of my life and encouraged me to never give up even in the face of overwhelming odds. I grope for words to express my deep feelings, love and affection to my younger brother.

Last but not least I would like to express my gratitude to all those who have helped, guided and supported me in one way or the other but have been inadvertently left out because all may not have been mentioned but none have been forgotten.

Needless to say, omissions are mine.

Name of the student- Swati Sharma

Dated:

Signature

Table of Content

List of Figures

List of Tables

List of Symbols

SN	Symbol	Description
1	$I(x,y)$	Cover Image
2	$I_w(x,y)$	Watermarked Image
3	$W(x,y)$	Random Noise
4	I_{max}	Maximum possible value of image pixel
5	$W(i,j)$	Original Watermark Image
6	$W'(i,j)$	Extracted Watermark Image
7	S_i	Ith combination in FL
8	$H^r(I)$	Order of fuzzy entropy
9	$H_{hy}(I)$	Modified hybrid entropy
10	E_w	Image pixels as white
11	E_b	Image pixels as black
12	μ	Degree of combination
13	G_x	Granient filter for I_x
14	G_y	Granient filter for I_y
15	A_{wat}	SVD decomposition of watermarked image
16	S_c	Singular matrix of cover image.
17	S_w	Singular matrix of watermark image
18	S_{wat}	Singular matrix of watermarked image
19	S_w^*	Singular matrix of extracted watermark
20	$A(x,y)$	DWT coefficients before embedding watermark
21	$A'(x,y)$	DWT coefficients after embedding watermark

List of Acronyms

Sr. no.	Acronym	Description
1	DCT	Discrete Cosine Transform
2	DWT	Discrete Wavelet Transform
3	DFT	Discrete Fourier Transform
4	SVD	Singular Value Decomposition
5	NN	Neural Network
6	SVM	Support Vector Machine
7	FL	Fuzzy Logic
8	FSVM	Fuzzy Support Vector Machine
9	FNN	Feed Forward Neural Network
10	BPNN	Back Propagation Neural Network
11	PSNR	Peak Signal To Noise Ratio
12	MSE	Mean Square Error
13	NC	Normalized Correlation

Abstract

Recently, digital image watermarking develops very fast and applies to many applications, such as military, communication, medical/healthcare, privacy protection, identification, media file archiving, broadcast monitoring, Remote Education and Insurance Companies, Secured E-Voting Systems, Digital cinema, fingerprinting and many federal or state-issued photo IDs such as a driver's license or passport. However, copyright protection, content authentication and ownership identification are the challenging issues of the open channel information. Digital watermarking is technique for inserting digital information into a multimedia document, which can be later extracted or detected for variety of purposes including multimedia security. In addition to providing security, this technique can also be used to recognize the source, owner, distributor or creator of the data. The factors such as Robustness, transparency, capacity, security and computational cost are needed to be consider in the general watermarking system. However, these important factors like robustness, transparency and capacity are hindering to each other. Therefore, we need to balance these factors. In recent years, different machine learning methods such as fuzzy logic, support vector machine (SVM) play an important role to keep the optimal balance between imperceptibility/transparency and robustness. In addition, to enhance the robustness and security of watermark, researchers are using machine learning methods. The thesis work is divided into five different chapters. Chapter wise description of the thesis report is described as follows:

Chapter 1 presents the introduction of data hiding techniques, different approaches of watermark, characteristics and applications of watermark. It also contains the brief discussion of spatial and transforms domain techniques and its brief performance comparison. The chapters also includes the brief introduction of different machine learning techniques, the performance measure parameters such as peak signal to noise ratio (PSNR), normalized correlation (NC), and bit error rate (BER) for the watermark algorithms.

Chapter 2 presents the literature survey based on transform and spatial domain watermarking techniques using machine learning techniques. In addition, the performance of existing watermarking method is also compared in tabular format.

Chapter 3 presents the DWT and Fuzzy logic based watermarking technique using digital image. The performance of the proposed method is extensively evaluated with different gain factors, different size of cover image and watermark image. In addition, the method is also evaluated for signal processing attacks. The experimental result shows that the proposed method is robust for the known attack with acceptable performance of the visual quality of the watermarked image.

Chapter 4 presents the multiple watermarking methods using fusion of DWT, DCT and SVD with Fuzzy logic. The performance of the proposed method is tested for different gain factors, different size of cover and watermark image. Experimental results show that the method is found to be robust for different signal processing attacks includes rotation, Resize, Gaussian noise, JPEG compression. The robustness is enhanced by using the fuzzy logic is applied on extracted watermark.

Finally, findings of the thesis and future directions are presented in **Chapter 5**.

CHAPTER – 1
Digital Image Watermarking Technique: An Introduction

1.1 INTRODUCTION

The digital media such as image, audio and video is an important way of communication in the world and being increasingly used for delivery of multimedia content, thus it is easy to manipulate, store, distribute or reproduce the data using different networking sites. This shows no difference in the quality between an original image and its copy image [1-5]. However, unrestricted copying and malicious tampering cause huge financial losses and problems for intellectual property right [6]. Therefore, information hiding has become an important research area. Steganography and watermarking is used as a data hiding technique for the protection of digital media. Steganography is a technique of hiding communication in which hidden content is embedded in some cover media so that there will not be any unauthorized users [7-11]. Watermarking is one of the new methods that provide protection against various attacks, data authentication and security to digital media. It is the process of embedding secret information in the form of signal called watermark into digital media so that this secret information can detected and extracted out to check the real owner or identity of digital media [12-13]. Watermarking is similar to steganography with additional requirement of robustness. In watermarking system watermark is embedded in such a way that it cannot be altered without making whole cover media meaningless. Digital watermarking came as a technique and a tool to overcome short comings of current copyright laws for digital data [14]. Digital watermarking systems have been proposed to provide content protection, authentication and copyright protection, protection against unauthorized copying and distribution. In this technique, it consists of protecting the illegal insertion of robust and imperceptible brand in a host image. The watermarking algorithms must be imperceptible to the naked eye, robust against attacks, blind which means the original image is not necessary for the detection and extraction of the brand [15-17].

Machine learning can improve the detection rate of watermarks after being attacked and contains numerous methods for different classification and patterns for recognition of problem. It also provides increasing level of automation in the knowledge engineering process by replacing time consuming activity with automatic techniques used for improvement of accuracy and efficiency [6-8]. Machine learning plays important role in industries, education, network security, computer graphics etc.

1.2 CHARACTERSTICS OF WATERMARK

There are various important characteristics of digital watermarking as discussed below [6]:

a. Imperceptibility: It deals with the perceptual transparency of the watermark. It is independent of the application and watermark should not be noticeable to the viewer nor should the watermark degrade the quality of the content.

b. Robustness: It is the capability of data to survive the host signal manipulation from both malicious and non malicious attacks. It can be achieved without affecting the quality of signal.

c. Data payload: The data payload of a watermark can be defined as the amount of information that it contains. It is a major requirement in a number of watermarking applications, where high embedding rate is highly desirous.

d. Security: The watermark security implies that the watermark should be difficult to remove or alter without damaging the cover image. The security requirement of a watermarking system can differ slightly depending on the application.

e. Computational cost: It is the cost of inserting and detecting watermarks in digital media content. So the speed requirements of inserting and detecting watermark is highly application dependent.

f. Key restrictions: There are different watermarking methods creating unique key for data and which requires owner of data to maintain these keys.

1.3 APPLICATIONS OF WATERMARK

There are various types of applications of watermarking as discussed below [8].

a. Copyright Protection: When a new work is produced, copyright information can be inserted as a watermark. In case of dispute of ownership, this watermark can provide evidence.

b. Broadcast Monitoring*:* This application is used to monitor unauthorized broadcast station. It can verify whether the content is really broadcasted or not.

c. Tamper Detection: Fragile watermarks are used for tamper detection. If the watermark is destroyed or degraded, it indicates presence of tampering and hence digital content cannot be trusted.

d. Authentication and Integrity Verification: Content authentication is able to detect any change in digital content. This can be achieved through the use of fragile or semi-fragile watermark which has low robustness to modification in an image.

e. Fingerprinting: Fingerprints are unique to the owner of digital content and used to tell when an illegal copy appeared.

f. Content Description: This watermark can contain some detailed information of the host image such as labelling and captioning. For this kind of application, capacity of watermark should be relatively large and there is no strict requirement of robustness.

g. Covert Communication: It includes exchange of messages secretly embedded within images. In this case, the main requirement is that hidden data should not raise any suspicion that a secret message is being communicated.

1.4 VARIOUS ATTACKS ON WATERMARK

There are various types of attacks of digital watermarking as discussed below [15]:

a. Active attacks: In active attacks hacker tries to remove watermark. They are aimed at distortion of watermark before recognition. This shows the problem in copyright protection, copy control etc.

b. Passive attacks: In passive attacks, hackers just tried to figure out that there is watermark and identify it. In this attack no damage or removal is done.

c. Forgery attacks: In forgery attacks hackers embed new valid watermark rather than removing one. In this hackers can easily manipulates the data and makes corrupted image genuine.

d. Collusion attacks: In collusion attacks hackers has the same intension as for the active ones but used slightly different approach. The hacker uses instances of same data to construct the new copy without watermark.

1.5 APPROACHES OF WATERMARK

The image watermarking techniques is divided into two domain methods [3-6]:

a. Spatial domain methods (least significant bit substitution, spread spectrum etc.) are more simple high capacity but are not robust against common signal processing attacks.

b. Transform domain methods (DWT, DCT and SVD etc.) are more robust against common signal processing attacks but the computational complexity is higher than spatial domain methods.

1.5.1 Spatial Domain Technique

Spatial Technique is used on the modified pixels data. Spatial technique is less complex as compare to the transform domain and requires less time and computational complexity. There are different spatial domain techniques which are as explained bellow:

a. Least Significant Bit

It is commonly used spatial domain technique in which randomly pixels of cover image are selected and watermark is embedded in least significant bits. For e.g.

Image:	10001000	10101001	11100011	11001100
Watermark:	1	0	0	1
Watermarked image:	10001001	10101000	11100010	11001101

b. Predictive Coding Schemes

This technique is more robust as compared to LSB. In this technique correlation between adjacent pixels is found. First set of pixels need to be embedded with watermark is taken and then difference between adjacent pixels is used to replace alternate pixels. At the receiver end cipher key is used for the retrieval of watermark**.**

c. Correlation-Based Techniques

In this technique a pseudo-random noise is added to an image and during decoding a correlation between two is found. If correlation value exceeds some threshold level watermark is found otherwise it is not. Let Iw represents watermarked image, pseudo-random noise W(x,y) can be added to cover image I using following equation:

$$I_w(x,y) = I(x,y) + K \times W(x, y) \quad (1)$$

Here K is Gain factor. If we increase the value of K, the robustness of watermarked image increases but quality of image decreases.

d. Patchwork Techniques

This technique partitions image into two subsets. Some operation is then applied to these subsets in opposite direction. For example if one subset is decreased by factor x, the other subset should be increased by same amount.

1.5.2 Transform Domain Technique

Transform Domain techniques are robust as compare to the spatial domain technique. In the given technique watermark is embedded in the transformed image and inverse is used to get the watermarked image. There are different types of transform domain techniques which are as explained bellow:

a. Discrete Wavelet Transform (DWT)

DWT is used for the transformation of an image from the spatial domain to the frequency domain by passing it through a series of low-pass filters and high-pass filters. The decomposition of each level produces four bands of data denoted by LL (Approximation sub band), HL (Vertical sub band), LH (Horizontal sub band), and HH (Diagonal sub band), where HH,HL and LH sub-band represent the finest scale wavelet coefficients and LL sub-band stands for the course-level coefficients. To obtain another level of decomposition, LL sub-band can further be decomposed [9-11]. This process is continued until the preferred number of levels determined by the application is reached. After the first level of decomposition, there are 4 sub-bands as LL1, LH1, HL1 and HH1. For each successive level of decomposition, the LL sub-band of the previous there level is used as the input. To perform second level decomposition, the DWT is applied to LL1 band which decomposes the LL1 band into the four sub- bands LL2, LH2, HL2, and HH2. To perform third level decomposition, the DWT is applied to LL2 band which decompose this band into the four sub-bands – LL3, LH3, HL3, HH3. Figure 1.1 represents the third level decomposition of the DWT.

This results in 10 sub-bands per component. LH1, HL1, and HH1 contain the highest frequency bands present in the image tile, while LL3 contains the lowest frequency band [14-16].

There are equations for high pass and low pass as given bellow:

$$H(w) = \sum_k h_k(-jkw) \qquad (2)$$

$$L(w) = \sum_k l_k(-jkw) \qquad (3)$$

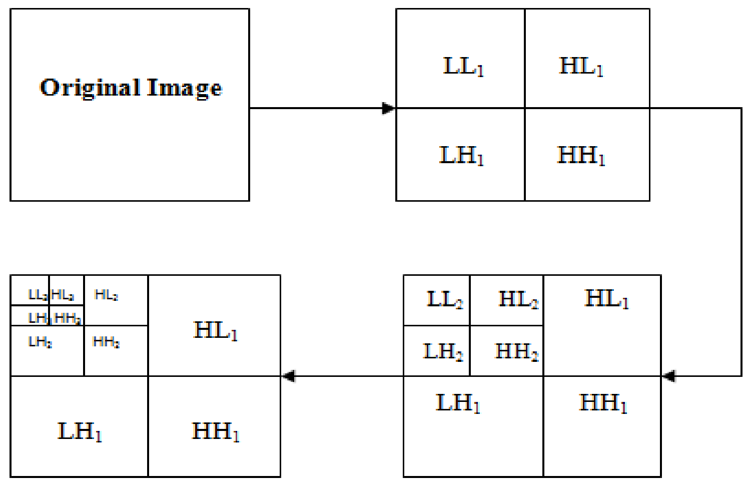


Figure 1.1: 3-Level Wavelet Decomposition

b. Discrete Fourier Transform (DFT)

DFT provides robustness against various geometrical attacks like rotation, scaling, translation etc. DFT decomposes image into sine and cosine form. DFT magnitude and phase coefficients are modified while embedding watermark. DFT is translation invariant because any kind of spatial shifts affects the phase representation of an image and the magnitude representation remains unaffected. It is considered in the field of watermarking in order to offer the possibilities of controlling the frequencies of the cover image signal. It is used to obtain the best solution of visibility and robustness [15-19].

Given 2-Dimensional signal f(x,y), then DFT is defined as:

$$F(k_1, k_2) = \beta \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} f(m,n) \exp\left(-\, {}^{i2\pi m k_1}/_{M} - {}^{i2\pi n k_2}/_{N} \right) \qquad (4)$$

Where value of $\beta = \sqrt{MN}$ and value of $i = \sqrt{-1}$. Now the inverse of DFT is as given bellow:

$$f(m,n) = \beta \sum_{k_1=0}^{M} \sum_{k_2=0}^{N} F(k_1, k_2) exp\left({}^{i2\pi m k_1}/_{M} + {}^{i2\pi n k_2}/_{N} \right) \qquad (5)$$

c. Discrete Cosine Transform (DCT)

DCT is related to discrete Fourier transform (DFT) in a sense that it transforms a time domain signal into its frequency components. The DCT however only uses the real parts of the DFT coefficient. DCT has a strong energy compaction property and most of the signal information tends to be concentrated in a few low-frequency components of the DCT. The JPEG compression technique utilizes this property to separate and remove insignificant high frequency components in images [18-24].

d. Singular Value Decomposition (SVD)

SVD is a numerical analysis tool used to analyze matrices. In this transformation, matrix can be decomposed into three matrices that are of the same size as original matrix and preserves both one-way and non-symmetric properties. When SVD is used in digital image the size of the matrices is not fixed. Singular values in a digital image are less affected if general image processing is performed and singular values contain intrinsic algebraic image properties. The singular values of the host image are modified to embed the watermark image by employing multiple singular functions [24-28]. Table 1.1 represents the comparison of Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) and Singular value Decomposition (SVD).

Table 1.1: Comparison of frequency domain techniques

Considered Parameters	DWT	DCT	SVD
Complexity	More Complex	Less complex compare to DWT	More complex
Robustness	More robust to various attacks of image	Robust to various attacks of image	Resist against common attacks on image
Applications	Science, engineering, mathematics and computer science	Signal and Image processing	Signal processing and statistics

1.6 MACHINE LEARNING TECHNIQUE

There are different Machine Learning Techniques which are as explained bellow:

a. Support Vector Machine (SVM)

SVM is a machine learning tool used for performing classification and detection tasks. In SVM algorithm, two sets of vectors are considered, one is of real numbers and the other is output vector. In order to minimize the number of errors the mapping should be constructed from input to output [7-11]. It contains classification task which involves with training and testing data instances, where each instance in the training set contains one “target value (class labels)” and several “attributes (features)”. The final goal of SVM is to produce a model by predicting a target value of data instances in the testing set which are given only the attributes [21]. It is used for the mapping between training set and positive and negative values. To learn the mapping: X € Y where x € X is some object and y €Y is a class label. We take the simplest case 2-class classification, so: x € R, y€ {+ or (-) 1}. A classifier function is defined as y=f(x, α), where α are the parameters of the function. We can also written as f(x, {w, b}) = sign (w.x+b).where w and b are some constants used to determine the test errors [24-26]. Training error is also called as empirical risk which is given by the equation:

$$R_{emp}(\alpha) = \frac{1}{m}\sum_{i=1}^{m} l(f(x_{i,}\ \alpha) y_i) = \text{Training error} \quad (6)$$

Test error ≤ Training error+ complexity of test model.

To reduce the test error the complexity function should be minimized.

b. Fuzzy Support Vector Machine (FSVM)

Fuzzy systems are those whose variables have domain fuzzy sets. Domain fuzzy sets are the training points which only belong to one class. These points do not provide the highly desired characteristics of learning and adaption [37]. The main idea is to construct a hyper plane that act as a decision space as the margin of separation between positive and negative. SVM is used to construct the optimal hyper plane for which this margin is maximized. FSVM is used to improve the training point errors. It is used to maximize the margin [42].

c. Neural Networks (NN)

A neural network represents a highly parallelized dynamic system with a directed graph topology that can receive the output information by means of reaction of its state on the input nodes. The ensembles of interconnected artificial neurons generally organized into layers of fields include neural networks [31]. Neural networks are classified as feed forward and feedback networks. The aim of this network is to train the net to achieve the balance between the ability to respond correctly to the input pattern that are used for training and the ability to provide good response to the input that are similar [32-35].

d. Fuzzy Logic (FL)

Fuzzy logic is a form of many-valued logic or probabilistic logic, it deals with approximate (rather than fixed and exact) reasoning. It has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Fuzzy logic has proven to be an excellent choice for many control system applications since it mimics human control logic [36] . It does not require precise inputs, is inherently robust, and can process any reasonable number of inputs. When we use fuzzy in image processing is called Fuzzy Image Processing, which is the collection of different fuzzy approaches. Fuzzy image processing includes all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing of the images depend on the selected fuzzy technique and on the problem to be solved [38-46].

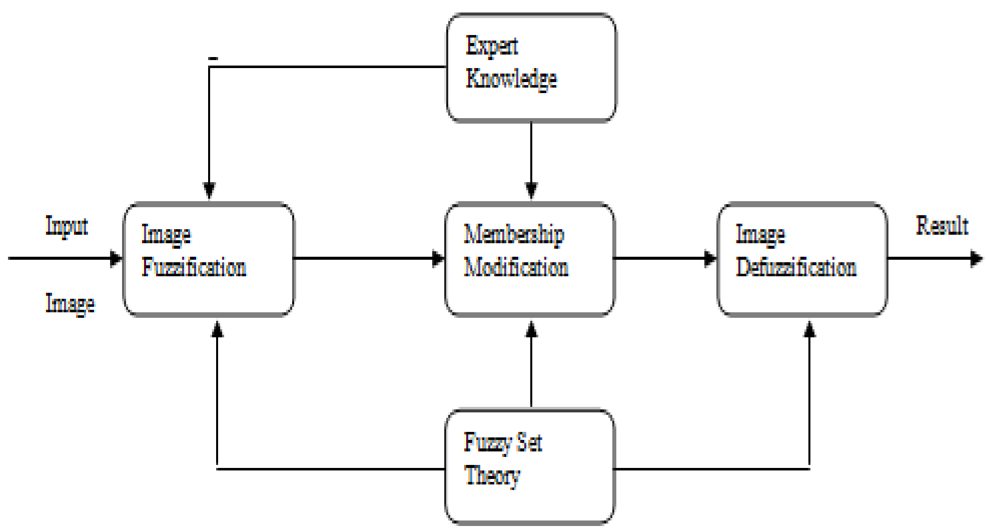


Figure 1.2: General Fuzzy Logic Structure

Figure 1.2 represents the general Fuzzy logic structure. Here is a list of general observations about fuzzy logic:

- Fuzzy logic is conceptually easy to understand.
- Fuzzy logic is tolerant to imprecise data.
- Fuzzy logic can be built on top of the experience of experts.
- Fuzzy logic can model nonlinear functions of arbitrary complexity

With all the components, a fuzzy logic system can be built in the following steps [43].

Step 1: Independent variables are selected as the key determinants or indicators of the dependent variable.

Step 2: Fuzzy sets are created for both independent and dependent variables. Instead of using the numerical value, fuzzy sets in terms of human language are used to describe a variable. The degree of truth that each variable belongs to a certain fuzzy set is specified by the membership function.

Step 3: Inference rules are built in the system. A fuzzy hedge may be used to tweak the membership function according to the description of the inference rules.

Step 4: The output fuzzy set of the dependent variable is generated based on the independent variables and the inference rules. After defuzzification, a numerical value may be used to represent the output fuzzy set.

Step 5: The result is then used for informed decision-making.

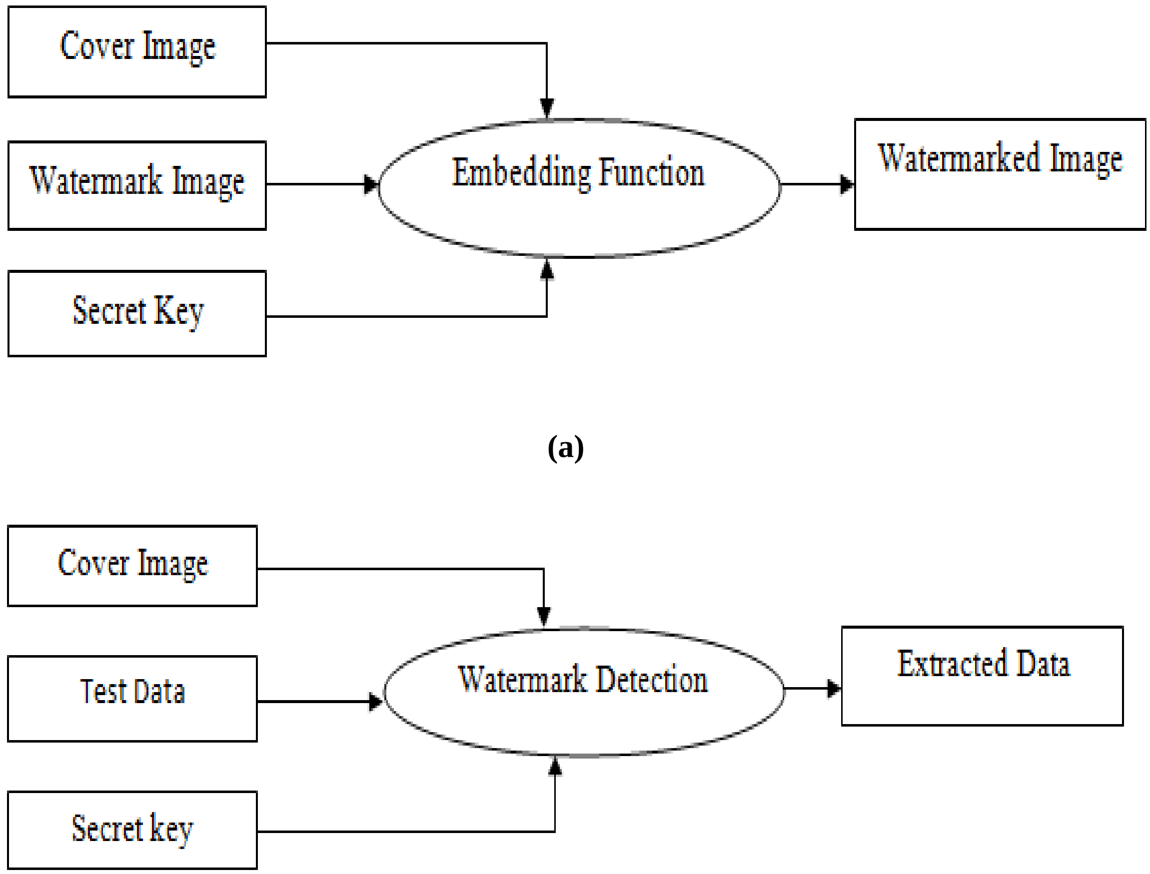
1.7 EMBEDDING AND EXTRACTION PROCESS

In general watermarking system consists of two processes, embedding and extraction. The embedding process is consisting of encoding. It is used to produce the watermarked image. The watermark embedding process takes a cover image (C), watermark image (W_I) and secret key (K) then it goes to embedded function gives watermarked image (W_E) [14]. The extraction process is consisting of recovery process. It is used to recover the corrupted image, which may or may not be the watermarked image. It takes cover image and watermarked with secret key to recover the watermark from the possibly corrupted image [16]. The watermark embedding and extraction process is given in Figure 1.3(a) and Figure 1.3(b). The watermark embedding process can be written as:

$$W_E = F(C, W_{I,} K) \tag{7}$$

Also, the watermark extraction process can be written as:

$$\text{Watermark (W)} = F\ (W \text{ or } C, W_E, K) \tag{8}$$



(a)

(b)

Figure 1.3: Watermark (a) Embedding process and (b) Extraction process.

1.8 PERFORMANCE MEASURE

The performance of watermarking algorithm is calculated on the basis of its robustness and imperceptibility. Performance is calculated on the basis of PSNR (Peak Signal to Noise Ratio). Large PSNR values indicate that the watermarked image more closely resembles the original image meaning that the watermark is more imperceptible. Generally, watermark with PSNR value greater than 35dB is acceptable. PSNR is as explained bellow:

$$PSNR_{dB} = 10 * \log_{10} \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} I^2(i,j)}{\sum_{i=1}^{M} \sum_{j=1}^{N} [I(i,j) - I_W(i,j)]^2} \tag{9}$$

Where I (i, j) represents the pixels of original image of size M×N and I_W (i, j) is the pixel of watermarked image of size M×N. the robustness of watermark algorithm is explained in terms of the Normalized Correlation (NC) [6]. It is used to calculate the difference between the original and watermark image. Its value is varies from 0 to 1. Ideally it should be 1 but the value above than 0.7 is acceptable [15].

$$\mathrm{NC} = \frac{\sum_{i=1}^{M} \sum_{J=1}^{N} W(i,j) \times W'(i,j)}{\sum_{i=1}^{M} \sum_{j=1}^{N} W(i,j)^2} \tag{10}$$

Where W (i, j) is pixel of original image and W' (i, j) is pixel of recovered image of size M×N. Bit Error Rate is defined as a ratio between number of incorrectly decoded bits and total number of bits [16]. It is used to evaluate the reliability of the text watermark. Therefore, lower bit error rate, better is the performance of watermarking algorithm. The bit error rate is computed as:

$$\mathrm{BitErrorRate} = \frac{\text{Incorrectly Decoded Bit}}{\mathit{Total\ Number\ of\ Bit}} \tag{11}$$

CHAPTER – 2

Literature Survey

This chapter presents the summary of existing watermarking method based on transform and spatial domain watermarking techniques using machine learning techniques. The important and relevant existing techniques are presented below. The summary of the reported methods is categorized into three parts.

(a)The existing methods based on spatial/transform domain hybrid technique using SVM

Vatsa et al. [11] proposed biometric based image watermarking algorithm where face image is embedded in the fingerprint. The embedding watermarking method based on Discrete Wavelet Transform (DWT) and Support Vector Machine (SVM). The experimental result is shown that the method is robust and the face image is resilient to geometric and frequency attacks. The integration of SVM improved the face recognition by 10%. Yen et al. [17] proposed a digital watermarking technique using spatial domain based on support vector machine. The watermarking technique uses only 128bits in training SVMs. To embed the watermark bits, the proposed scheme modifies blue channels of the central and surrounding pixels at same time. Watermarks are embedded in spatial domain and extracted directly from a watermarked image without the requirement of original image. The experimental result shows that the proposed scheme provides high PSNR of a watermarked images and low extraction error rate. Jianzhen et al. [19] proposed a RST (Rotation, Scaling and translation) invariant watermarking technique utilizing SVM and image moments for synchronization. In watermarking technique to estimate RST transform parameters SVM is utilized to learn the image geometric pattern represented by six combined low order image moments. The experimental result shows that scheme can resist JPEG compression, noise and geometric attacks. B.Jagadeesh et al.[13] proposed a robust and blind Image watermarking algorithm for copyright protection of images. The embedding watermarking method is used by DWT based on the support vector machine. The experimental result shows that method is secured and robust for various attacks. However, the value of NC and PSNR is less than 0.9711 and 35dB for most of the attacks. Jain et al. [14] proposed a watermarking algorithm based on support vector machine using color image. In the embedding process, the watermark is embedded into the discrete wavelet domain of the original image and extracted by training support vector machine. In addition, the method is using momentum coefficient to reduce the error and increase the rate of the learning. The experimental results have been shown that the method is imperceptible against signal processing attacks. However, the value of PSNR is below than 27 dB for most of the attacks. B.Jagadeesh et al.[24] proposed a novel image watermarking method in discrete wavelet transform domain using support vector machine. The embedding watermarking method is used to extract the watermark from the watermarked image even after different image processing attacks. The experimental result shows that the given algorithm is secure and robust to different image attacks.

(b) The existing methods based on transform domain technique using Neural Network

Zhang et al. [36] proposed a technique of image watermarking capacity using neural network. The watermarking technique is used for hiding the information in the form of images and watermarking is used as a form of communication. The experimental result shows that the attraction basin of associative memory decided watermarking capacity. Vafaei et al. [34] proposed a robust blind watermarking method. The watermarking method uses the Neural Networks in Discrete Wavelet Transform domain. The neural networking technique is used to maximize the strength of watermark image. The experimental result shows that method is robust and imperceptible to various attacks. Thai et al.[33] proposed a technique for image classification using support vector machine and artificial neural network. In the technique, image is divided into sub images and each sub image is classified into the responsive class by ANN then SVM compiled all the classified result of ANN. The Experimental result shows the feasibility of the technique. Yahya et al. [20] proposed a model for information security using stego SVM classification. The embedding technique uses LSB in image steganography that hides data behind a cover-image in a spatial and discrete cosine transform (DCT) domain. The technique proposed a new model that utilizes Human Visual System (HVS) and embedding technique through shifted LSB called Stega SVM- Shifted LSB in DCT domain to preserve the imperceptibility and increase the robustness of stego-images.

(c) The existing methods based on spatial/transform domain technique using Fuzzy Logic

Lei Li et al.[50] proposed an image watermarking scheme using spatial domain based on Fussy Support Vector Machine (FSVM). In the embedding process, the 8 * 8 block of the cover image is divided into sub-block of the texture features as input vectors using support vector machine. The image sub-block is divided into a weak texture and a strong texture. The strong texture information is embedded into the cover image. The method has been shown that the robustness of the FSVM based method is better than SVM based method against important attacks. Shi et al. [28] proposed a new color watermark embedding technique with circulation, based on non-overlapping SVD for hiding important information in images. In the watermarking method cover image is decomposed into small watermarks and then watermark is embedded into one single block with circulation. The experimental result shows that scheme is robust against different image attacks. U.Lande et al. [52] proposed novel hardware for an adaptive encrypted watermarking method based on fuzzy logic. In the given technique fuzzy logic method is used for data fusion by using human visual system in a wavelet domain. This technique uses encryption and digital watermarking to give complete security to the digital information. The experimental result demonstrate that the given technique give high robustness of the proposed algorithm against the geometric distortion such as rotation and scaling. Ramamurthy et al. [39] proposed a robust digital image watermarking scheme using neural network and fuzzy logic approach. The approach shows comparison to embed watermark into host image using quantization in DWT domain based on BPNN (Back Propagation Neural Network) and DFIS (Dynamic Fuzzy Inference System). The experimental result shows the watermarking technique is robust and imperceptible to the attacks. Jeon et al. [46] describes a novel color image enhancement method using fuzzy membership functions. The given model uses three fuzzy functions i.e. Image Fuzzification, Membership function rules and image defuzzificatiom to map the intensity. The simulation result shows that the proposed approach is practical and gives satisfactory results in all databases. Mahashwari et al.[38] proposed a technique which uses the fuzzy method for image enhancement. This technique is used to reduce impulsive noise, sharpen the edges with the help of different image enhancement techniques. In the given approach fuzzy techniques is used to manage the uncertainty and imperfection of an image which can be represented as a fuzzy set. T.Sridevi et al. [30] proposed a digital image watermarking model implemented by using fuzzy logic based on transform domain. In this technique reference image is used instead of original image and threshold value is calculated for middle and high frequency bands. A transform domain with the help of fuzzy logic system is used to embed the watermark in the reference image. The experimental result shows that value of PSNR is not varying much but the visual quality is good. Sandhu et al. [47] proposed novel hardware for an adaptive encrypted watermarking method based on fuzzy logic. In the given technique fuzzy logic method is used for data fusion by using human visual system in a wavelet domain. This technique uses encryption and digital watermarking to give complete security to the digital information. The experimental result demonstrate that the given technique give high robustness of the proposed algorithm against the geometric distortion such as rotation and scaling. Pandey et al. [54] proposed the image compression based technique by using the fuzzy logic. The Hybrid Comparison Method is a combination of both the DWT and DCT Image Compression method. In the given method when more than one compression technique are applied by using fuzzy logic to compressed one image for higher compression ratio and for getting clearness of the image. The experimental result shows that it reduces the Errors. Dammavalam et al. [51] proposed a fuzzy logic method to fuse images from different sensors, in order to enhance the quality of the image and compared proposed method with two other methods i.e. image fusion using wavelet transform and weighted average discrete wavelet transform based image fusion using genetic algorithm. The experimental result obtained from proposed fuzzy based image fusion approach improves quality of fused image as compared to method of wavelet transform based image fusion and weighted average discrete wavelet transform based image fusion using genetic algorithm. Banergee et al.[53] proposed a new approach for efficient fuzzy logic based fractal image compression in DCT domain using quad tree algorithm. This method deals with the fuzzy logic, which is a strong tool to handle vagueness, and since images are vague in terms of pixel values fuzzy logic is most appropriate logic for its analysis. In the proposed technique one domain block is considered for each range block and searched only for matched contrast scaling. Hence the outcomes fractal code does not contain coordinates of the matched domain block. The experimental result shows that the encoding time required is very small as compare to conventional fractal image compression (CFIC) techniques. Moreover the PSNR and compression values are higher than CFIC. Alshennawy et al. [44] proposed the edge detection technique developed for satellite image using fuzzy logic concept. Fuzzy logic helps to find all the edges associated with an image by checking the relative pixel values. After the testing of fuzzy conditions the appropriate values are allocated to the pixels in the window under testing to provide an image highlighted with all the associated edges. Mohindru et al.[49] proposed a technique of integrating multiple images of the same scene into a single output fused image. It minimizes redundancy and reduces uncertainty and extract all the useful information from the source images. The paper represents the image fusion using the combination of wavelet transform and adaptive fuzzy logic. The experimental result shows that the image is robust to different image attacks. Yu et al. [42] proposed a multi criteria decision analysis tool for credit risk evaluation using fuzzy set theory. The tool is developed to initially allocate results obtained from alternative competing credit evaluation techniques in the form of fuzzy opinions, then aggregated into a group consensus and, lastly, defuzzified into a discrete numerical value to support an ultimate credit decision. Human reasoning, expert knowledge and imprecise information are considered valuable inputs in the estimation of operational risk.

This chapter has presented detailed review of watermarking techniques based on spatial and frequency domain using machine learning techniques. The different watermarking techniques are use to learn about the parameters based on the performance. The use of different techniques is to improve the robustness, imperceptibility, visibility and quality of the digital image. In the above review we concluded that by using the combination of different machine learning techniques with transform and spatial domain techniques helps in improving the different factors. Table 2.1 represents the comparison of wavelet based watermarking using different machine learning language.

Table 2.1: Summary of some wavelet based watermarking using machine learning

Sn.	**Authors, Year**	**Technique used**	**Watermark Type, Size**	**Results (Maximum value)dB**
1	Vatsa et al. [11], 2005	DWT, SVM	Fingerprint , Face Image(512×512) / Extracted Face Image	Value of verification of face and fingerprint ranges from 0-1 and shows accuracy is improved by 10%.
2.	Yen et al.[17], 2006	Spatial domain method , SVM	Color image of Lena, Baboon , Monkey , House (512×512)/ Binary image of Rose (64×64)	PSNR= 45.536
3.	Jianzhen et al.[19], 2009	DWT, SVM	Grey scale image of lena (512×512)/ logo image	PSNR= 39.12
4.	Li et al.[50], 2010	Spatial Domain, SVM, FSVM	Grey scale image of Cameraman (256×256)/ logo image	PSNR=20.866,NC=0.986
5.	Jain et al.[20],2011	DWT, SVM	Lena, Baboon (256×256)/ logo color image (32×32)	PSNR=43.499
6.	Ramamurthy et al. [39], 2012	DWT , Neural Network, Fuzzy logic	Office_4 cover image (512×512)/ Barbara grey scale image (64×64)	PSNR=51.3593,NC=0.99 65
7.	B.Jagadeesh et al.[13], 2013	DWT, SVM	Lena , Goldhill and pepper (512×512)/ logo(64×64)	PSNR=45.15,NC=1
8.	Vafaei et al.[34], 2013	DWT, Neural Network	Grey scale image of Lena , Baboon, Airplane, Barbara(512×512)/ logo watermark Binary image (8×8)	PSNR=48.25, NC=0.99
9.	B.Jagadeesh et al.[24],2014	DWT ,SVM	Grey scale images of Goldhill, Mandrill and Peppers (512×512) /logo image (64×64)	PSNR=45.94,NC=0.961
10.	Yahya et al.[20], 2015	DCT, SVM	Lena, Baboon of size 1024 bits/ logo image	PSNR=49.86, NC=1.0
11.	Mohindru et al.[49], 2016	DWT, Fuzzy logic and neural network	Grey scale image of Lena, Airplane(512×512)/ logo image	PSNR= 47.96, NC= 0.94

CHAPTER – 3

DISCRETE WAVELET TRANSFORM WITH FUZZY LOGIC

ABSTRACT

In this chapter, DWT and Fuzzy logic based watermarking technique using digital image is discussed. In this approach, DWT watermarking is used to embed the watermark into host image in combination with Fuzzy logic for Edge Detection. Cover image is decomposed using 3-level DWT to obtain (LL3, LH3, HL3 and HH3) sub bands. LL3 sub band is selected and applied to embed the watermark. Increasing number of levels increase the imperceptibility of watermarked image. When watermark was extracted it was different from original watermark, because it also depends on the scaling factor used. It suppresses various types of noise and interferences to recover the watermark image similar to embedded watermark.

3.1 INTRODUCTION

From last few years, the digital information is copied, distributed. So the protection of this multimedia content is important. Watermarking technique and Steganography is used for the protection for digital content. In watermarking, digital information is embedded in the cover image so that the secret information can be detected and extracted out to check the real owner or identity of digital media. It is also used to overcome shortcomings of current copyright laws for digital data. The advantage of watermarking technique is that the watermark should not affect the quality of cover image and it should be robust for different signal processing attacks. The performance of the proposed data is evaluated with DWT at third level and then Fuzzy logic is used to improve the given performance measure. Fuzzy logic process is divided into three parts i.e. Fuzzification, Membership function and Defuzzification. Dammavalam et al. [51] compared the proposed method with other two methods to enhance the quality of the image using wavelet transform and fuzzy logic. It uses the image fusion using wavelet transform and weighted average discrete wavelet transform based image fusion using genetic algorithm. The experimental results shows that quality of fused images is improved as compared to method of wavelet transform based image fusion and weighted average discrete wavelet transform based image fusion using genetic algorithm. Mahashwari et al.[38] proposed a technique which uses the fuzzy method for image enhancement. This technique is used to reduce impulsive noise, sharpen the edges with the help of different image enhancement techniques. In the given approach fuzzy techniques is used to manage the uncertainty and imperfection of an image which can be represented as a fuzzy set Ramamurthy et al. [39] proposed a robust digital image watermarking scheme using neural network and fuzzy logic approach. The approach shows comparison to embed watermark into host image using quantization in DWT domain based on BPNN (Back Propagation Neural Network) and DFIS (Dynamic Fuzzy Inference System). The experimental result shows the watermarking technique is robust and imperceptible to the attacks. The brief discussion about DWT and Fuzzy Logic is as explained:

a. DWT (Discrete Wavelet Transform)

DWT of digital image provides multi-resolution representation of an image which helps in interpreting image information. It transforms the two-dimensional digital image into four quadrants of different frequencies i.e. LL, LH, HL, HH. The low frequency part LL can be split again into more quadrants of high and low frequencies i.e. LL1, LH1, HL1 and HH1 and LL1 can be further decomposed into LL2, LH2, HL2 and HH2 until the signal is fully decomposed [38]. The coefficients obtained by applying DWT to cover image (C) are:

$$C_{LL}^{I} = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} g(x)\, g(y)\, H_{LL}^{I-1}\,(2a-x)(2b-y) \tag{12}$$

$$C_{LH}^{I} = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} g(x)\, h(y)\, H_{LL}^{I-1}(2a-x)(2b-y) \tag{13}$$

$$C_{HL}^{I} = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} h(x)\, g(y)\, H_{LL}^{I-1}(2a-x)(2b-y) \tag{14}$$

$$C_{HH}^{I} = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} h(x)\, h(y)\, H_{LL}^{I-1}(2a-x)(2b-y) \tag{15}$$

Here a, b =1, 2, 3….., N-1, I is the level of DWT transform and h(x), g(x) are the impulse responses.

b. Fuzzy Logic and Fuzzy Set Theory

This section introduces some basic concepts in fuzzy set theory and a comparison with other methods used for risk assessment and decision-making [40-45]. Fuzzy logic is used when system is either difficult to predict or difficult to model by conventional methods. System with large input output tends to be difficult to model using mathematical techniques [41]. These systems have typically high dimensionality and have degree of uncertainty in many parameters. Fuzzy logic is the one of the application used to solve these types of problems. It is used to represent the uncertainties and imprecise values in an understandable form. In fuzzy logic value is plotted using membership function [43]. Each set has its own membership function which determines degree of truth that an element belongs to the set. Fuzzy logic is based on the theory of fuzzy sets, which is a generalization of the classical set theory. The theory of fuzzy sets is a generalization of the classical set theory. Fuzzy Image Processing (FIP) is a collection of different fuzzy approaches to image processing. Fuzzy image processing includes all approaches that understand, represent and process the images, their segments and features as fuzzy sets [45-47]. The representation and processing of the images depend on the selected fuzzy technique and on the problem to be solved.

To implement fuzzy logic technique to a real application requires the following three steps:

1. Fuzzification – convert classical data or crisp data into fuzzy data or Membership Functions (MFs)
2. Fuzzy Inference Process – combine membership functions with the control rules to derive the fuzzy output
3. Defuzzification – use different methods to calculate each associated output and put them into a table: the lookup table. Pick up the output from the lookup table based on the current input during an application

Inference Rule in Fuzzy Logic

With logical operations on fuzzy sets, inference rules can be built to establish the relationship among different variables. One type of fuzzy inference rule is called the max-min inference. Fuzzy logic starts with the concept of a fuzzy set. A fuzzy set is a set without a crisp, clearly defined boundary. It can contain elements with only a partial degree of membership. To understand what a fuzzy set is, first consider the definition of a classical set [51].

If A and B, then C: The maximum degree of truth for C is the lesser of the degree of truth for A and that for B.

If A or B, then C: The maximum degree of truth for C is the greater of the degree of truth for A and that for B.

If not A, then C: The maximum degree of truth for C is one deducted by the degree of truth for A.

In an image I with dimension MxN and levels L (based on individual pixel as well as a collection of pixels) are listed below. rth Order Fuzzy Entropy:

$$H^r(I) = (-1|k)\sum_{i=1}^{k}\left[\{\mu(s_i^r)log\mu(s_i^r)\} + \left\{\{1-\mu(s_i^r)\}log\{1-\mu(s_i^r)\}\right\}\right] \quad (16)$$

Where s_i^r denotes the *i*th combination (sequence) of r pixels in I; k is the number of such sequences; and μ (s_i^r) denotes the degree to which the combination - s_i^r, as a whole, possesses some image property μ [49].

Hybrid Entropy:

$$H_{hy}(I) = -P_w logE_w - P_b logE_b \quad (17)$$

$$E_w = (1|MN)\sum_{m=1}^{M}\sum_{n=1}^{N}\mu_{mn}\,.\,exp(1-\mu_{mn}) \quad (18)$$

where μ_{mn} denotes the degree of "whiteness" of the (m , n) pixel. P_w and P_b denote probability of occurrences of white (μ_{mn} =1) and black (μ_{mn}=0) pixels respectively; and E_w and E_b denote the average likeliness (possibility) of interpreting a pixel as white and black respectively.

De-fuzzification

Defuzzification is a process of estimating the value of the dependent variable based on the resulting fuzzy set after applying the fuzzy inference rule [47]. There are three types of defuzzification method. These methods are as explained bellow:

Average Method: The average method numerical value of the dependent variable in the output fuzzy set.

Average of maximum method: The average numerical value of the dependent variable with the maximum degree of truth in the output fuzzy set.

Centroid method: The weighted average numerical value of the dependent variable in the output fuzzy set. The weight is the degree of truth.

Advantage of using Fuzzy logic

In fuzzy logic does not need to know detailed knowledge of the system and system takes decision by using the rules.

Fuzzy logic systems allow for the modeling and inclusion of contraction in a knowledge base and also increases the system autonomy the rules in the knowledge base function independent of each other.

Compensatory as opposed to rule based where a single rule can bring undesirable outcome and also helpful in deleting the borderline cases.

3.2 EMBEDDING AND EXTRACTION PROCESS

The watermark embedding and extraction process is presented below. Figure 3.1(a) and Figure 3.1(b) show the watermark embedding and extraction process respectively.

3.2.1 Embedding Process:

Embedding process describes how Watermark image is embedded into the cover image [42]. So embedding process is as explained bellow:

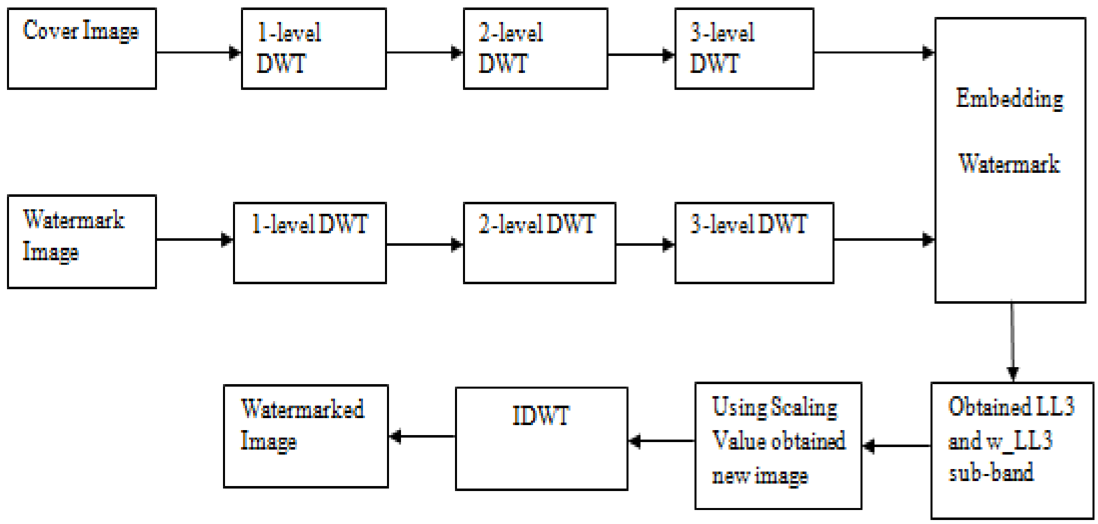
1. Select cover image of size 512×512 and convert it into grayscale.
2. Apply third- level DWT transform on cover image to decompose it into corresponding sub bands. Decomposition is applied in approximation sub band.
3. Select watermark image of same size and convert it into grayscale.
4. Apply Third-level DWT transform on Watermark image to decompose it into corresponding sub bands. The decomposition is applied on LL (Approximation Sub-band).
5. In the given process 'k' is used as the scaling factor, to get the new watermark image. New watermark image is generated when cover image is embedded with the watermark image.
6. Change LL3 sub band of cover image with the modified w_LL3 sub band at level 3.

   Watermarked image = LL3 + k×w_LL3
7. Apply Inverse Discrete Wavelet Transform (IDWT) to get watermarked image Watermarkedimage_final.

   Watermarkedimage_level1= idwt2 (Watermarkedimage, LH2, HL2, HH2,'haar');

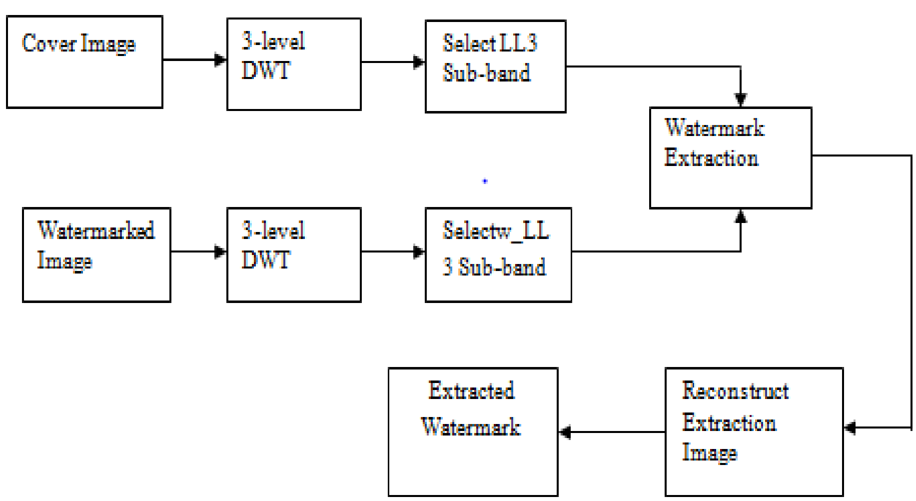
   Watermarkedimage_level2= idwt2 (Watermarkedimage_level1, LH1, HL1, HH1,'haar');

   Watermarkedimage_final= idwt2 (Watermarkedimage_level2, LH, HL, HH,'haar');
8. Apply attacks and noise to the watermarked image to check the imperceptibility of the proposed algorithm.



(a)

3.2.1 Extraction Process



(b)

Figure 3.1: Watermark (a) Embedding and (b) Extraction Process

Extraction process describes how Watermark image is extracted from watermarked image [42]. So extraction process is as explained bellow:

1.Select the Watermarked image.

2.Apply third-level DWT transform on cover image to decompose it into corresponding sub-bands.

3.Select the E_LL3 sub-band from the decomposition process and use the scaling factor to recover the image.

4.Recovered image=E-LL3-LL3/k;

5.Use inverse IDWT on the recovered image to obtain the inverse of extracted image.

3.3 EXPERIMENTAL RESULTS

In this algorithm experiments were conducted using MATLAB R2012a software. Grayscale cover and watermark images of different sizes were used as shown in figure. The butterfly image was converted into transform domain by using three-level DWT. LL3 sub band was selected to embed watermark. Singular matrices of watermark were then embedded into the singular matrices of LL3 sub band of butterfly image with some scaling factor to obtain watermarked image (Watermark1) [44]. IDWT was then applied to watermarked image to convert it into transform domain. The butterfly image containing watermark is shown in figure. There is very negligible difference between the original butterfly image and watermarked image. There is some difference between the original watermark and the extracted watermark. The imperceptibility of watermarked was increased using fuzzy logic [46].The Figure 3.2 represents the flow diagram of edge detection of fuzzy logic. The algorithm was tested for butterfly image and Watermark1 for different scaling factors. Fuzzy Logic is applied in the embedding process [47]. In fuzzy logic edge detection is used as a boundary between two uniform regions. This process can detect an edge by comparing the intensity of neighboring pixels. However, because uniform regions are not crisply defined, small intensity differences between two neighboring pixels do not always represent an edge. Instead, the intensity difference might represent a shading effect. Edge detection problems are fuzzy in the nature. Singular matrices of watermark were then embedded into the singular matrices of LL3 sub band of butterfly image with some scaling factor to obtain watermarked image (Watermark1). IDWT was then applied to watermarked image to convert it into transform domain. The butterfly image containing watermark is shown in figure. There is very negligible difference between the original butterfly image and watermarked image. The watermark extracted from the watermarked image is shown in Figure 8.

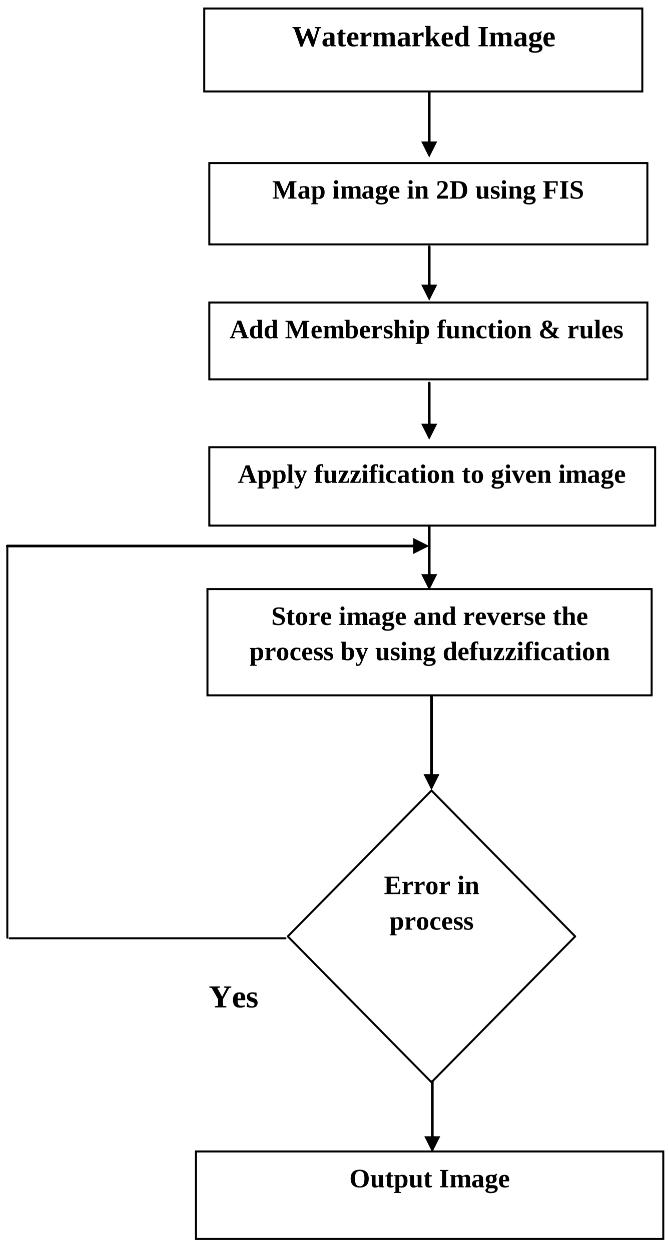


Figure 3.2 : Flowchart of Edge Detection

There is some difference between the original watermark and the extracted watermark. The imperceptibility of watermarked was increased using fuzzy logic. The algorithm was tested for butterfly image and Watermark1 for different scaling factors. Fuzzy Logic is applied in the embedding process. Figure 3.3 represents PSNR and NC performance of the method at different gain factor.

Table3.1: PSNR and NC performance of the method at different gain

SN	GAIN FACTOR	PSNR(db)	NC(without Fuzzy logic)	NC(with Fuzzy logic)
1	0.1	59.47	0.0575	0.4868
2	0.3	57.33	0.1156	0.5721
3	0.5	55.89	0.4833	0.6347
4	0.7	52.97	0.7524	0.9138

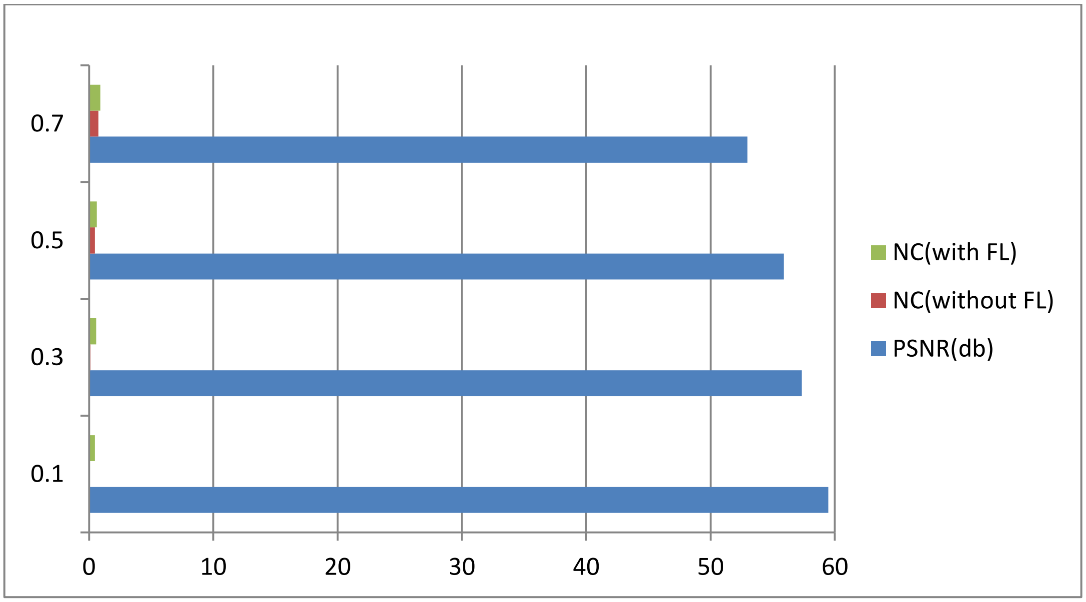


Figure3.3: PSNR and NC performance of the method at different gain Factor

.

In fuzzy logic edge detection is used as a boundary between two uniform regions. This process can detect an edge by comparing the intensity of neighboring pixels [43-50]. However, because uniform regions are not crisply defined, small intensity differences between two neighboring pixels do not always represent an edge. Instead, the intensity difference might represent a shading effect. Figure 3.4 represents the NC and PSNR performance for different size of cover and watermark image at gain = 0.7 respectively.

Table3.2: NC and PSNR performance for different size of cover and watermark image at gain = 0.7

SN	Cover Image	Watermark Image	Cover image size	Watermark image size	PSNR(db)	NC	NC(using Fuzzy logic)
1	Butterfly	Logo_1	512×512	512×512	46.34	0.4178	0.9067
2	Flowers	Logo_3	256×256	32×32	44.38	0.3811	0.8904
3	Houses	Logo_4	128×128	16×16	42.78	0.3456	0.8791
4	Flower_1	Logo_5	512×512	64×64	47.48	0.4234	0.8804
5	Lena	Logo_6	128×128	64×64	42.89	0.3561	0.8721

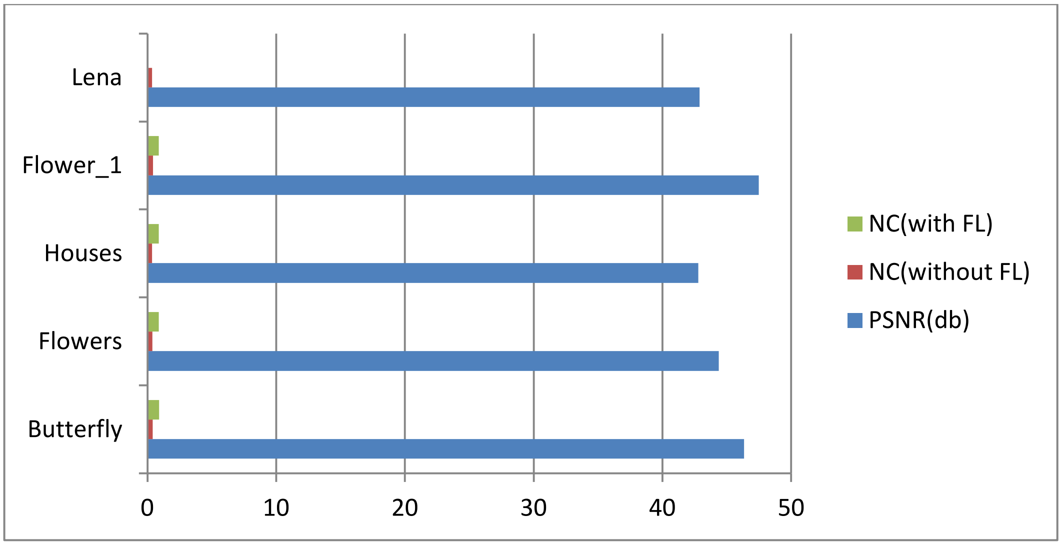


Figure 3.4: NC and PSNR performance for different size of cover and watermark image at gain= 0.7

Edge detection problems are fuzzy in the nature. In edge detection pixel should become darker or brighter after processing. This process is concerned with the different rules. In this way in which one is going to model and process the fuzzy sets for antecedent and consequent of rules. Table 3.1 shows different performance values at different gain factor. In Type-1 Fuzzy logic are modeled as Type-1 fuzzy sets, whereas in Type-2 Fuzzy logic are modeled as Type-2 fuzzy sets. In this implementation the range of pixels intensities are selected as edge pixels [39]. This range can be obtained by Type-2 fuzzy outputs.Type-2 FIS is implemented using mamdani model with Gaussian type membership function defined over the range of antecedent variables. The same sets of rules are used for Type-2 FIS as of Type-1 FIS [43]. The only difference between Type-1 and Type-2 FIS is the way the fuzzy sets are defined and processed for antecedent and consequent variables in this implementation. Type-2 FIS has been implemented in MATLAB using edges acquired by Type-2 FIS.

A different value shows that Type-2 FIS provide enhanced flexibility in choosing the pixel values. The algorithm also shows the different values of PSNR and NC at different gain factor of different images [44-45]. It tells us how imperceptibility values are improved by using fuzzy logic. Table 3.2 and Table 3.3 show values of performance measure with different size and with attacks.

Table 3.3: NC performance of the proposed method for different attacks at gain = 0.7

SN	Attack	NC(without Fuzzy logic)	NC(with Fuzzy logic)
1	Salt and paper(density 0.05)	-0.1717	0.6276
2	Salt and paper(density 0.03)	-0.1147	0.6316
3	Salt and paper(density 0.02)	-0.0813	0.6390
4	Gaussian(mean=0, variance=1)	0.1885	0.5356
5	Rotation 90	-0.3432	0.6392
6	JPEG 60	0.2253	0.5839
7	JPEG 30	0.2195	0.5765
8	JPEG 10	0.2124	0.5721

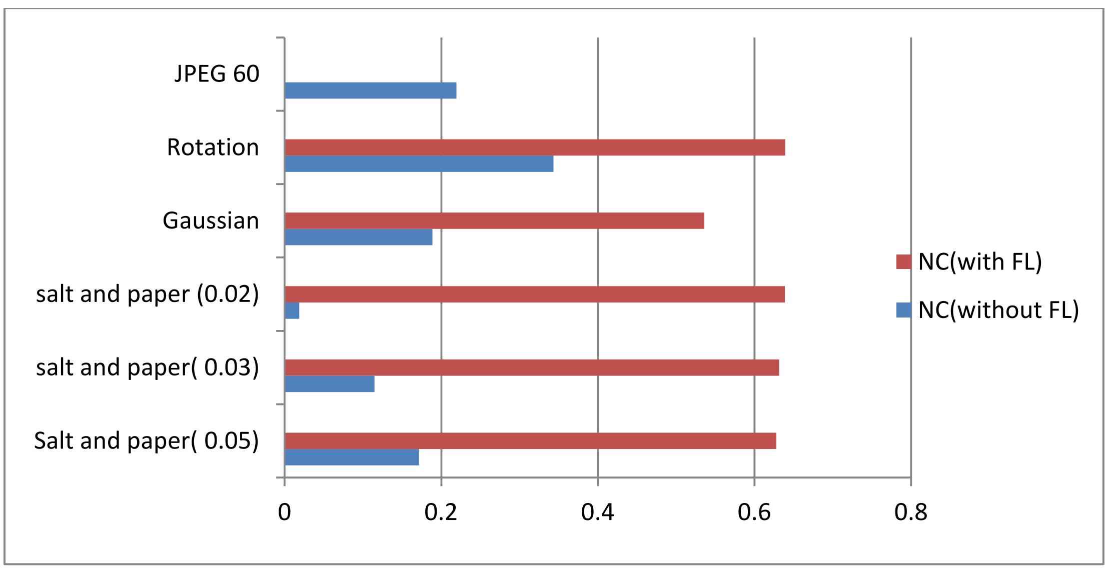


Figure 3.5: performance of the proposed method for different attacks at gain = 0.7

The process is as explained bellow:

1. Select cover image of size 512×512 and convert it into grayscale as shown in Figure 3.3.

2. Apply Third-level DWT transform on cover image to decompose it into corresponding sub bands. Decomposition is applied in approximation sub band.
3. Select watermark image of same size and convert it into grayscale as shown in Figure 3.4.
4. Apply Third-level DWT transform on Watermark image to decompose it into corresponding sub bands. The decomposition is applied on LL (Approximation Sub-band).

Figure3.6: Cover Image 1

Figure 3.7: Watermark Image1

Figure3.8: Watermarked Image

5. In the given process 'k' is used as the scaling factor, to get the new watermark image. New watermark image is generated when cover image is embedded with the watermark image. Change LL3 sub band of cover image with the modified w_LL3 sub band at 3-level.

   Watermarked image = LL3 + k×w_LL3

   The Watermarked image is represented in Figure 3.5.

6. First read the grayscale watermarked image. We use im2double for rescaling the given data of the image.

   Igay1 = imread(“Watermarkedimage.jpg”);

   Igray= im2double(Igray);

7. We use the CDatamapping for scaling the axis of the image. To display an indexed image, set the CDataMapping property to direct so that the values of the data array are used directly as indices into the figure. When the image command is used with a single input argument it set the value CDataMapping to direct. The image is shown in Figure 3.6 .

   Image(Igray, ‘CDateMapping’, ‘scaled’); clormap(gray);

   Title(‘Input image in grayscale’);

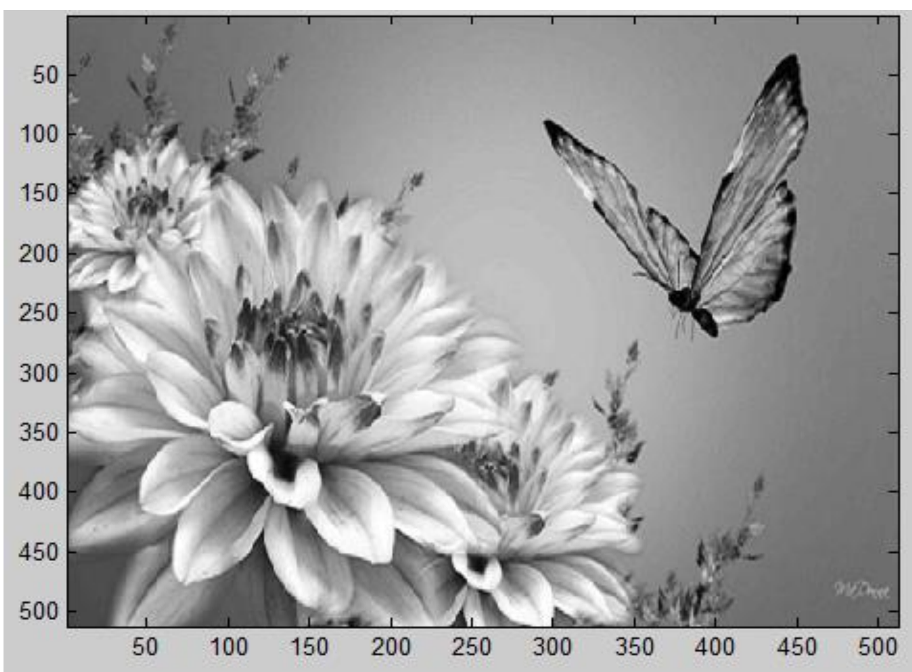


Figure 3.9: Grayscale Original Image using Mapping in Fuzzy logic

8. Fuzzy edge detection uses the variables to calculate the image gradient used to locate the breaks in uniform region. Gx and Gy are the gradient filters. When image is convolve with Gx, using conv2 function to obtain a matrix containing the x-axis

gradients of image. The gradient values are in the [-1 1] range. In the same way it is applied to obtain the Gy gradients of image.

Gx = [-1 1];   Gy = Gx;

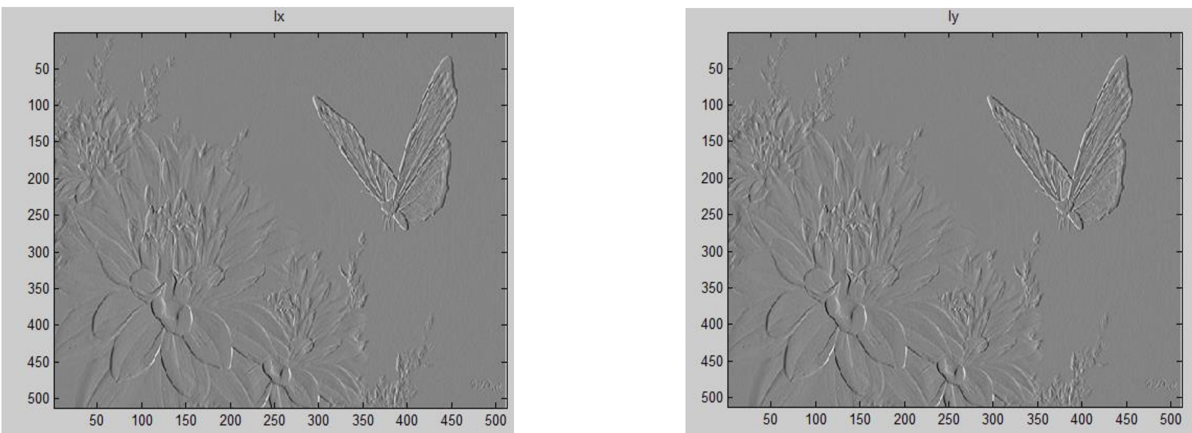
Ix=conv2 (i, Gx,'same');

Iy=conv2 (i, Gy,'same');

Image (Ix,'CDataMapping','scaled');   colomap('gray'), title('Ix');

Image (Iy,'CDataMapping','scaled');   colormap('gray'), title('Iy');

The input image of Ix and Iy is shown in Figure 3.7(a) and Figure 3.7(b).



(a) **(b)**

Figure3.10: Input image of (a) Ix and (b) Iy

9. EdgeFIS is used as the fuzzy inference system for edge detection. It is used to specify a zero mean Gaussian membership function for each input. If the gradient value for a pixel is Θ then it belong to the zero membership function with a degree of 1.

   EdgeFIS = newfis ('edge Detection');

   EdgeFIS = addvar (edgeFIS,'input','Ix', [-1 1]);

   EdgeFIS = addvar (edgeFIS,'input','Iy', [-1 1]);

10. Sx=0.1 ;   Sy= 0.1;

    Sx and Sy specify the standard deviation for the zero membership function for the Ix and Iy inputs. We can change the value of Sx and Sy to adjust the edge detector performance.

11. edgeFIS =addmf (edgeFIS,'input',1,'zero','gaussmf', [Sx 0]);

EdgeFIS =addmf (edgeFIS,'input', 2,'zero','gaussmf', [Sy 0]);

EdgeFIS =addvar (edgeFIS,'output',’Iout’,[0 1]);

It is used to specify the intensity of edge detected image as input and output of edgeFIS. The degree of membership is shown in figure 3.8.

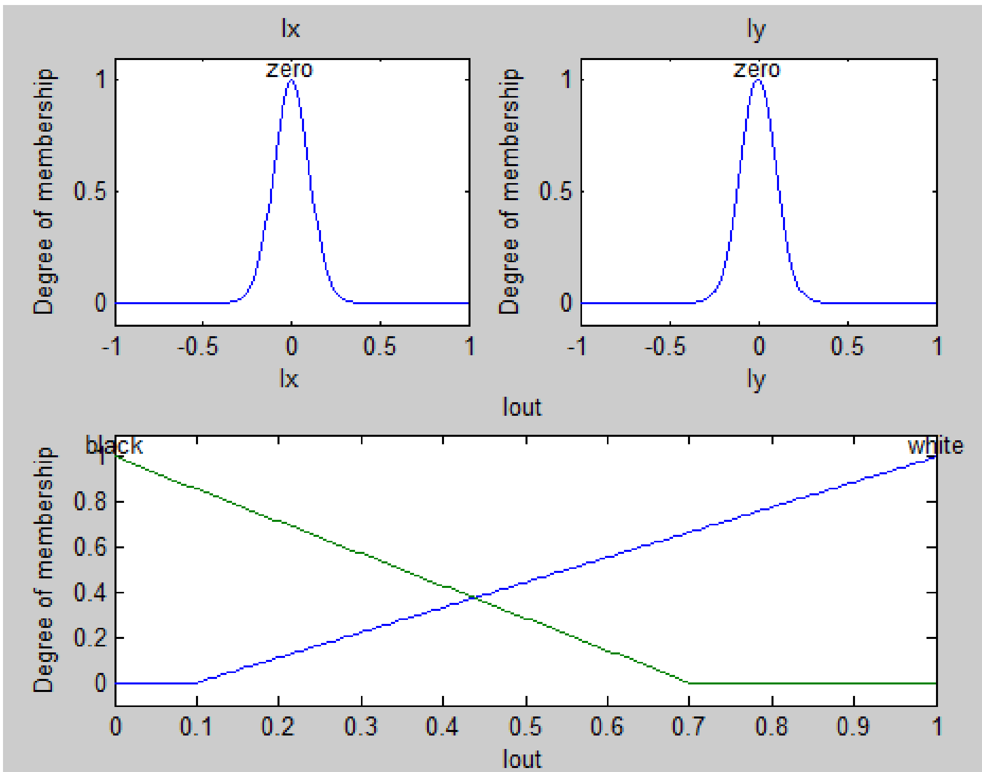


Figure 3.11: Degree of Membership Function

12. wa= 0.1; wb=1; wc=1; ba= 0; bb=0; bc=0.7;

edgeFIS= addmf (edgeFIS,'output',1,'white','trimf',[wa wb wc]);

edgeFIS=addmf (edgeFIS,'output',1,'black','trimf',[ba bb bc]);

These values are used to adjust the edge detector performance. The triplets specify the start, peak and end of the triangles of the membership function. The parameter inference intensity of the detected edges. Subplots are used to plot the membership function of the input and output of edge detection.

13. Ieval is used to evaluate the output of the edges detector for each row of pixels in image using the corresponding Ix and Iy as inputs. In the end plot results .

14. By using Ieval output image , reverse all the process of fuzzification in reverse order for defuzzification and generate the image as shown in the edge detection Figure 3.9.

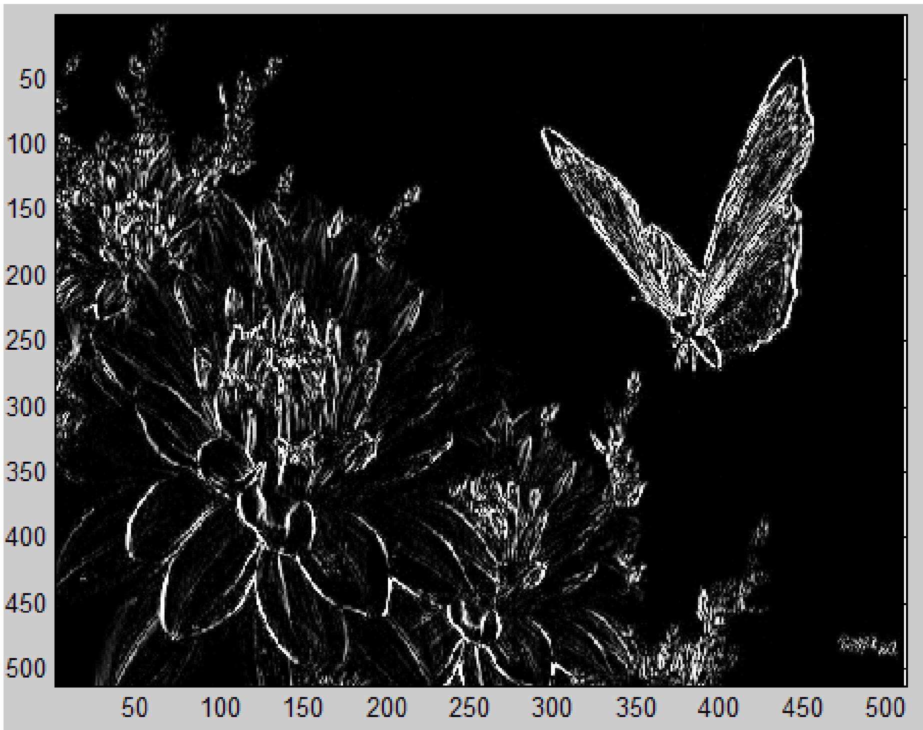


Figure 3.12: Edge Detection using Fuzzy Logic

3.4 CONCLUSION

The given paper presents DWT and Fuzzy logic based watermarking technique using Digital image. The watermarking techniques are used to improve the parameters based on the performance and Fuzzy logic makes the proposed system more robust. In addition, the method is also evaluated for signal processing attacks. The experimental result shows that the proposed method is robust for the different image attack.

CHAPTER – 4

Robust Digital Image Multiple Watermarking Using Fuzzy Logic

ABSTRACT

In this paper, a robust digital image watermarking scheme based on Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), Singular value decomposition (SVD) with Fuzzy logic is proposed. In the embedding process, grayscale cover image is decomposed up to third- level DWT. Low frequency sub band and high frequency sub band is transformed by DCT and then calculated image is again transformed by SVD. The 'S' vector of watermark information is embedded in the 'S' component of the cover image. Watermark is extracted using an extraction algorithm. In order to enhance the robustness performance of the image watermark, fuzzy logic is applied to the extracted watermark to reduce the effects of different noise applied on the watermarked image. Therefore, the proposed scheme is secure to different image attacks. The proposed technique may find the potential solution to existing security problem in many applications such as facial pattern recognition, air conditioners, medical diagnosis and treatment plans, stock trading etc.

4.1 INTRODUCTION

In recent years, the digital resolution resulted in increasing amount of applications using digital multimedia technology. This digital multimedia content such as image, audio and video are being increasingly used for delivery of multimedia content, so it is easy to manipulate, store, distribute or reproduce the digital data. However, unrestricted copying and malicious tampering cause huge financial losses and problems for intellectual property right. Therefore, protection of this multimedia content has become essential job [1-5]. Watermarking is the process of embedding secret digital information called watermark into digital media, so that this secret information can detected and extracted out to check the real owner or identity of digital media. It is also used to overcome shortcomings of current copyright laws for digital data. The advantage of watermarking technique is that the watermark should not affect the quality of cover image and it should be robust for different signal processing attacks [6-9]. There are different applications in which watermarking is used such as Content identification and management, Content protection for audio and video content, Forensics and piracy deterrence, Content filtering, Communication of ownership and copyrights, digital document security. According to domain, watermarking techniques can be classified as spatial domain and transform domain techniques. In spatial domain techniques (least significant bit substitution, spread spectrum etc.) are more simple high capacity but are not robust against common signal processing attacks and are modified by using pixel values in less time. In case of transform domain techniques (DWT, DCT and SVD etc.) are more robust against common signal processing attacks but the computational complexity is higher than spatial domain methods [7, 10-13]. Experimental results are obtained with two different watermarking images and also with different gain factors. These results show that the proposed method is robust to different attacks. When transformed techniques are used then to make images more robust fuzzy logic is applied. To perform image processing using fuzzy logic, three stages must occur i.e. Fuzzification, Membership Function and Defuzzification. Fuzzification is used to modify the membership values of a specific data set or image which is transformed from gray-level plane to the membership plane using Fuzzification. Defuzzification is used to decode the results to get the output image [48-51]. Pandey et al [54] proposed the image compression based technique by using the fuzzy logic. The Hybrid Comparison Method is a combination of both the DWT and DCT Image Compression method. In the given method when more than one compression technique are applied by using fuzzy logic to compressed one image for higher compression ratio and for getting clearness of the image. The experimental result shows that it reduce the Errors. Yu et al. [42] proposed a multi criteria decision analysis tool for credit risk evaluation using fuzzy set theory. The tool is developed to initially allocate results obtained from alternative competing credit evaluation techniques in the form of fuzzy opinions, then aggregated into a group consensus and defuzzified into a discrete numerical value to support an ultimate credit decision. Human reasoning, expert knowledge and imprecise information are considered valuable inputs in the estimation of operational risk. Shi et al. [28] proposed a new color watermark embedding technique with circulation, based on non-overlapping SVD for hiding important information in images. In the watermarking method cover image is decomposed into small watermarks and then watermark is embedded into one single block with circulation. The experimental result shows that scheme is robust against different image attacks. The theoretical background of hybrid technique is as explained bellow:

a. Discrete Cosine Transform (DCT)

DCT domain watermarking can be classified into Global DCT watermarking and Block based DCT watermarking. In block based DCT watermarking image is segmented into non-overlapping blocks. Then forward DCT is applied to all these blocks [23]. In DCT, for embedding the watermark information, image is divided into different frequency bands. The first transform coefficient is called DC coefficient and all others are AC coefficients. After applying some block selection and coefficient selection criteria. Watermark is embedded by modifying selected coefficient with watermark. After that inverse transform is applied to convert image into spatial domain [26]. The general equation for DCT is defined by the following equation:

$$F(u) = \left(\frac{2}{N}\right)^{\frac{1}{2}} \sum_{i=0}^{N-1} \gamma(i).cos\left[\frac{\pi.\mu}{2.N}(2i+1)\right] f(i) \tag{18}$$

Corresponding inverse DCT transform is simple $F^{-1}(u)$, i.e.: where

$$A(i) = \begin{cases} \frac{1}{\sqrt{2}} \; for \; \gamma = 0 \\ 1 \;\; otherwise \end{cases} \tag{19}$$

b. Singular Value Decomposition (SVD)

It decomposes matrix of host image into 3 rectangular matrices i.e. U, S and transpose (T) of V. SVD is very efficient in representing the intrinsic properties of an image. S is diagonal matrix whose diagonal entries is singular values and is in descending order. These singular values represent the brightness of an image. U and V are orthogonal square matrices in which columns are left and right singular vectors [34]. These singular vectors represent the geometry of an image. Let I is square matrix then SVD can be represented as:

$$I = USV^T$$

4.2 EMBEDDING AND EXTRACTION PROCESS

The proposed algorithm has two different parts, the embedding and extraction process. Figure 4.1(a) and Figure 4.1(b) illustrates the watermark embedding and extraction process respectively.

4.2.1 Watermark embedding process

The embedding process is described as given [45]. Watermark image is embedded into cover image using following steps: -

1. Apply third-level DWT transform on cover image to decompose it into corresponding sub bands i.e. LL3, HL3, HH3 and LH3.
2. Select LL and HL sub band of cover image to apply DCT component.

   I = DCT (LL3); A = DCT (LH3);

3. Image is transformed using discrete cosine transform then SVD is applied to DCT coefficients. It partitions the given image into three matrices U, S and V.

   $U_1\ S_1\ V_1^T \longleftarrow$ SVD (I); $U_2\ S_2\ V_2^{\ T} \longleftarrow$ SVD (A);

4. Same process is applied on components of watermark image to obtain its corresponding image which is transformed with DCT and then with SVD to generate given three matrices. I1 shows the watermark 1 and A1 represents watermark2.

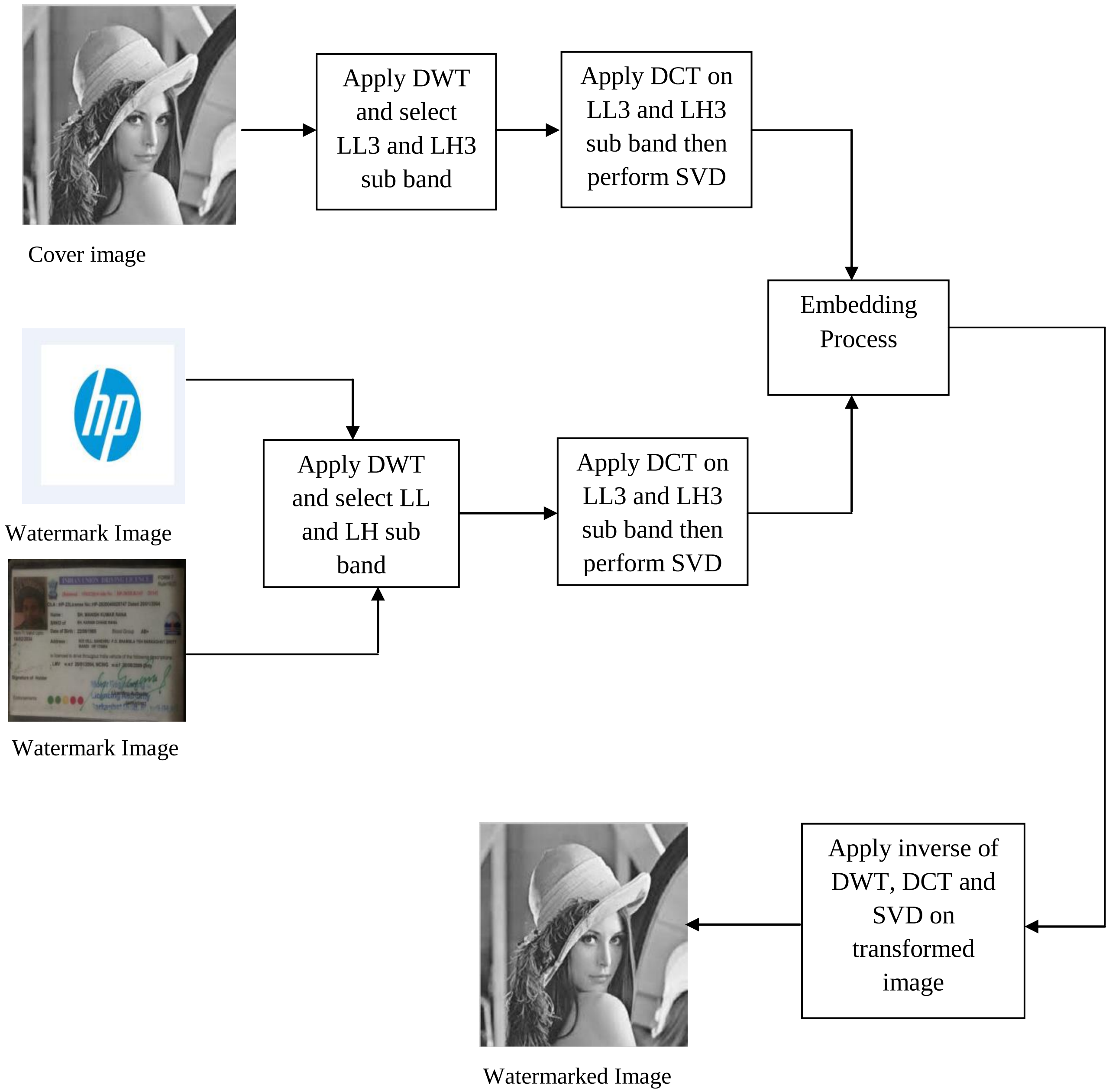
   I1 = DCT (LL); A1 = DCT (LH);

   $U_{11}\ S_{11}\ V_{11}^T \longleftarrow$ SVD (I1); $U_{21}\ S_{21}\ V_{21}^{\ T} \longleftarrow$ SVD (A1);

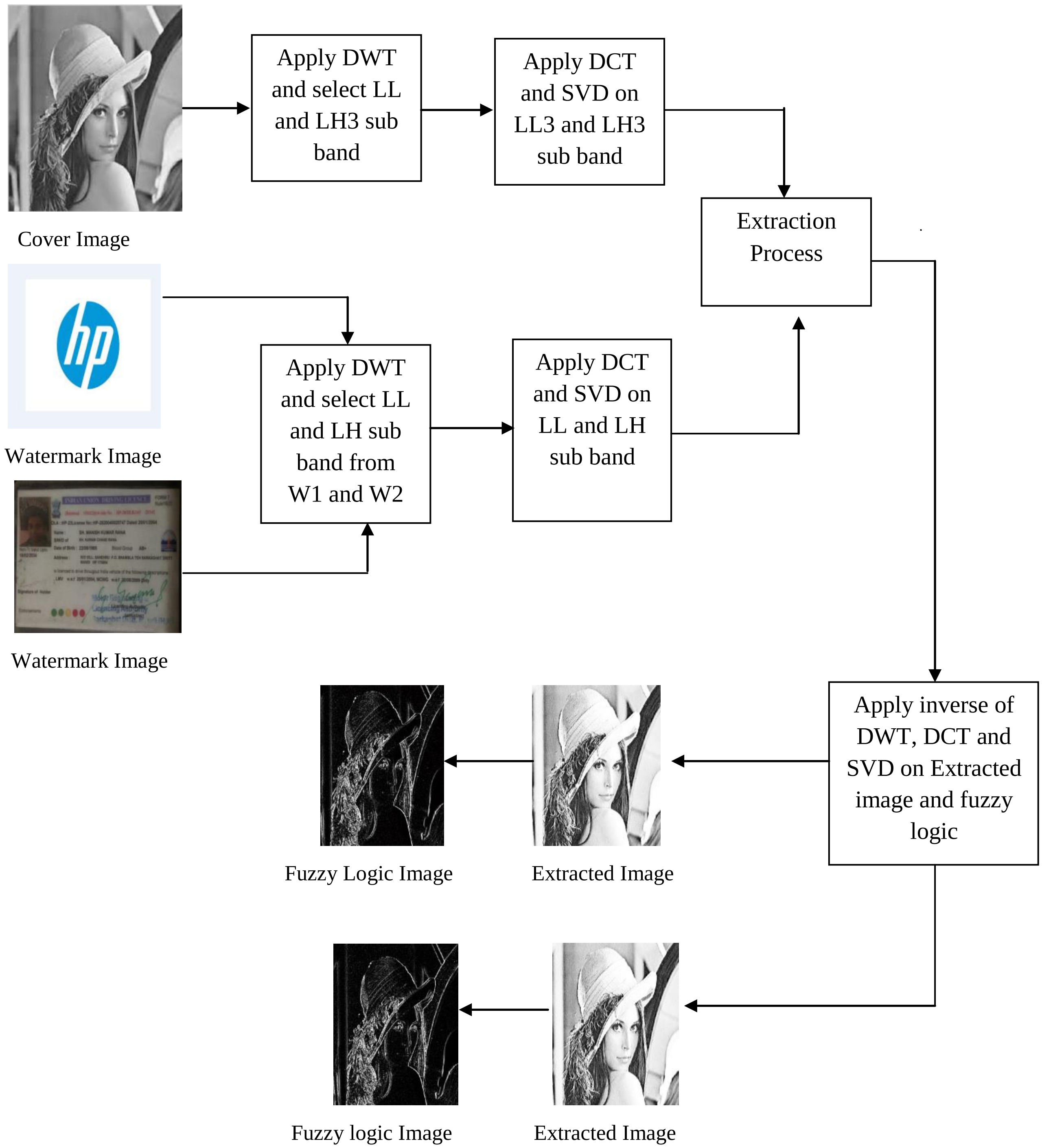
5. Modify the singular values of components LL3 and LH3 sub band of cover image with the singular values of watermark image. Here K is defined as the scaling factor which controls the embedding and extraction process. It works as the key used to embed the watermark into cover image.

   $I_{new1} \longleftarrow S_1 + k \times S_{11}$; $I_{new2} \longleftarrow S_2 + k \times S_{21}$;

6. Apply inverse DWT to all sub bands LL3, LH3, HL3, HH3 and then choose LL3 and HL3 sub band to apply the inverse of DCT then transformed image is used to apply inverse of SVD.
7. Apply attacks and noise to the watermarked image to check the robustness of the proposed algorithm.


Cover image
Apply DWT and select LL3 and LH3 sub band
Apply DCT on LL3 and LH3 sub band then perform SVD
Embedding Process
Watermark Image
Apply DWT and select LL and LH sub band
Apply DCT on LL3 and LH3 sub band then perform SVD
Watermark Image
Apply inverse of DWT, DCT and SVD on transformed image
Watermarked Image

(a)



(b)

Figure 4.1: Watermark (a) Embedding and (b) Extraction Process

4.2.2 Watermark Extraction Process

The extraction process is described as given bellow [45]. Watermark image is extracted from watermarked image using following steps: -

1. Apply third-level DWT transform on cover image to decompose it into corresponding sub bands i.e. LL3, LH3, HL3 and HH3.
2. Select LL3 and HL3 sub band to apply DCT transform and then SVD on given components of cover image to partition it into three matrices U, S and V.

   I2 = DCT (LL3); A2 = DCT (LH3);

   $U_{31}\ S_{31}\ V_{31}^{T} \longleftarrow$ SVD (I2); $U_{32}\ S_{32}\ V_{32}^{T} \longleftarrow$ SVD (A2);
3. Apply similar process on components of watermark images to obtain its corresponding matrices similar to step 2. I3 shows first watermark image and A3 represents the second watermark image.

   i. I3 = DCT (LL); A3 = DCT (LH);

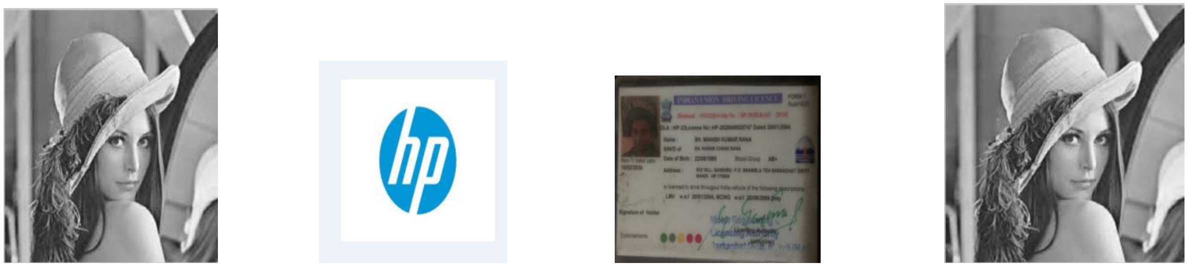
   $U_{41}\ S_{41}\ V_{41}^{T} \longleftarrow$ SVD (I3); $U_{42}\ S_{42}\ V_{42}^{T} \longleftarrow$ SVD (A3);

4. Obtain singular values of watermark image from the singular values of LL and HL sub band of watermarked image and cover image by using following equations:

   $I_{21} \longleftarrow (S_{31} - S_{41})/k$ $I_{11} \longleftarrow (S_{32} - S_{42})/k$
5. Fuzzy logic is then applied to extracted watermark to remove noise and interferences in order to improve its robustness.

4.3 EXPERIMENTAL RESULT

We describe the performance of the digital image watermarking based on DWT, DCT and SVD with Fuzzy logic. In this method, multi watermarking is used to evaluate the robustness of different grayscale images. The size of cover image is 512 × 512 and both the watermark image is 128× 128. Quality of watermark image is calculated by using factors PSNR (Peak Signal Noise Ratio) and NC (Normalized Correlation). To test the robustness of the proposed method, the watermarked image was tested against image processing attacks i.e. rotation, Resize, Gaussian noise, JPEG compression. To achieve the better performance, fuzzy logic is applied to the proposed method.



(a) (b) (c) (d)

Figure 4.2: (a) Cover Image, (b) and (c) Watermark Image and (d) Watermarked Image

Figure 4.2(a), Figure 4.2(b) and Figure 4.2(c) shows the cover image and watermark image and (d) represents the watermarked version of the image. To embed the watermark image in cover image we use to sub bands because low frequency component contains maximum energy, so embedding in these coefficients can increase the robustness without damaging the image fidelity. High resolution sub band helps to easily locate the edge pattern in the image. In this method the PSNR and NC performance is compared from table 4.1 to table 4.9 by using different sub bands of DWT.

Table4.1: PSNR and NC performance of the proposed method at different gain

SN	GAIN FACTOR	PSNR(db)	NC(without Fuzzy logic)		NC(with Fuzzy logic)	
			W1	W2	W1	W2
1	0.1	47.28	0.8645	0.8991	0.9323	0.9494
2	0.3	46.74	0.8690	0.9007	0.9408	0.9578
3	0.5	46.07	0.8711	0.9152	0.9491	0.9687
4	0.7	45.78	0.8861	0.9349	0.9502	0.9835

Table 4.1 to Table 4.3 it shows the comparison of LL and LH sub band. Table 4.1 represents the values of PSNR and NC without using attacks with different gain factors. The maximum NC value without using Fuzzy logic is 0.9349 and 0.8861 and with Fuzzy logic is 0.9735 and 0.9502 at gain factor 0.7. Figure 4.3 and Figure 4.4 also represents the values of PSNR and NC without using attacks with different gain factors using different watermark image. In Table 4.2, the method shows the PSNR and NC value with different size of cover and watermark images. According to the different size of images the level of DWT also varies.

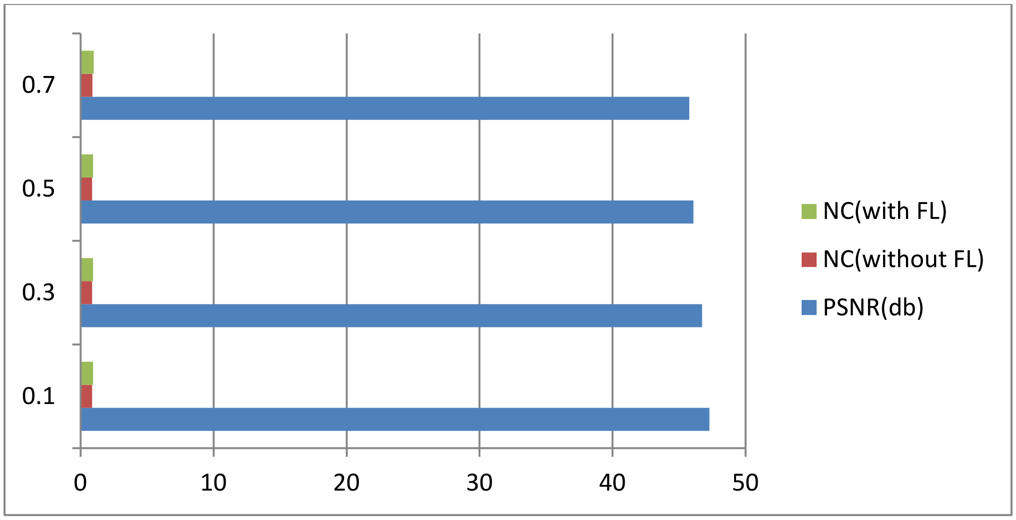


FIGURE 4.3: PSNR and NC performance for watermark 1 with different gain factors

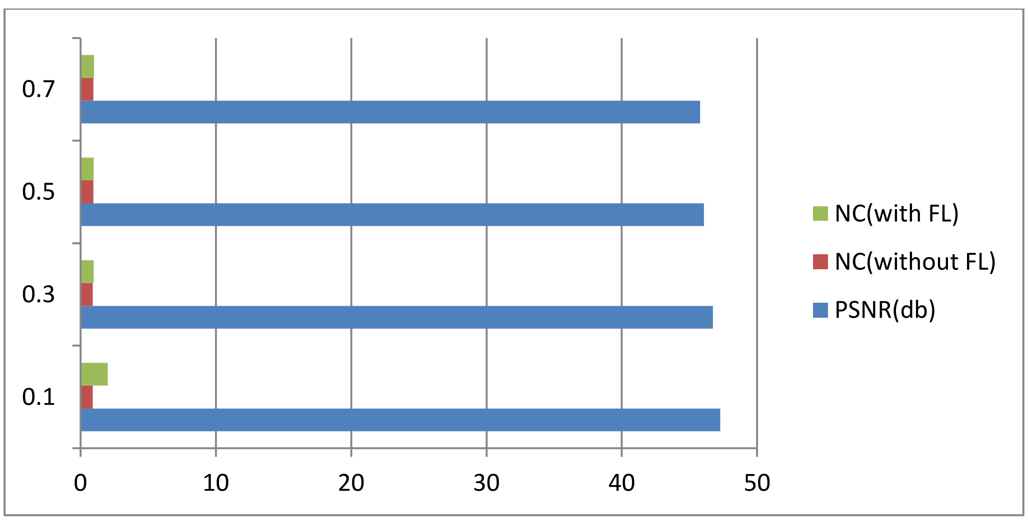


FIGURE 4.4: PSNR and NC performance for watermark 2 with different gain factors

Table 4.2: NC and PSNR performance for different size of cover and watermark image at gain = 0.7

SN	Cover Image	Watermark Image	Cover image size	Watermark image size	PSNR(db)	NC(without using fuzzy logic)		NC(using Fuzzy logic)	
						W1	W2	W1	W2
1	Butterfly	W1,W2	512×512	512×512	48.96	0.8406	0.8847	0.9176	0.9384
2	Flowers	W1,W2	256×256	32×32	48.43	0.8338	0.8676	0.9098	0.9302
3	Houses	W1,W2	128×128	16×16	47.98	0.8213	0.8316	0.8948	0.9295
4	Lotus	W1,W2	512×512	64×64	44.21	0.8109	0.8490	0.8794	0.9062
5	Lena	W1,W2	128×128	64×64	46.94	0.8167	0.8356	0.8838	0.8924
6	Earth	W1,W2	256×256	64×64	47.24	0.8179	0.8492	0.8891	0.9297

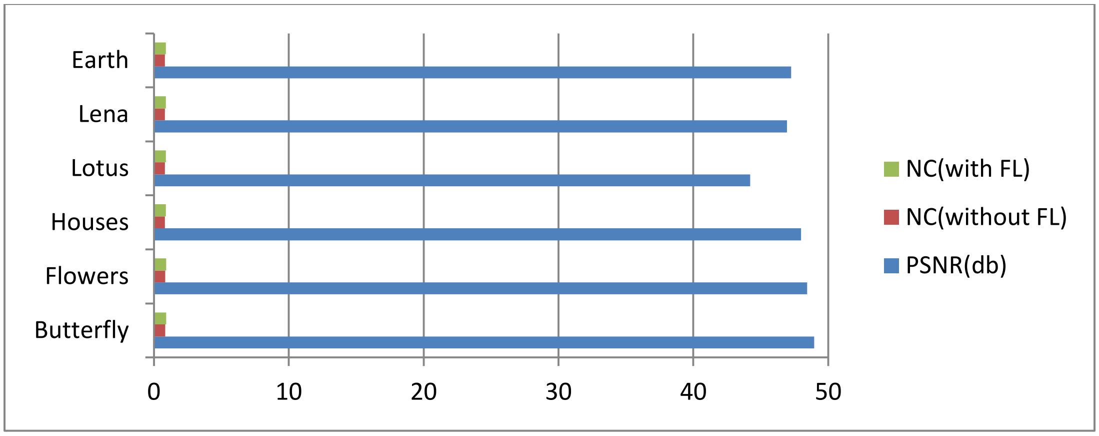


FIGURE 4.5: NC and PSNR performance for different size of cover and watermark 1 image at gain= 0.7

Figure 4.5 and Figure 4.6 also represents the graph of the PSNR and NC value with different size of cover and watermark images. According to the different size of images the level of DWT also varies. It shows the values using different watermark image. In Table 4.3, it represents the performance with different attacks on the image. It shows the robustness of the method when different attacks applied on the image. These three tables contain the values which are measured in LL and LH sub bands. Figure 4.7 and Figure 4.8 also represents the graph of the NC performance value with different images attacks. It shows the values using different watermark image.

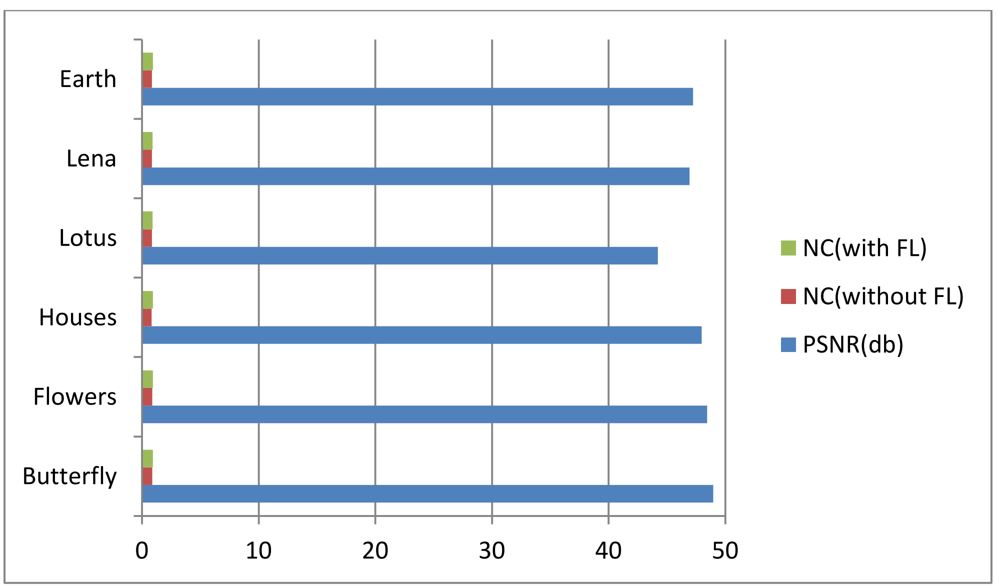


FIGURE 4.6: NC and PSNR performance for different size of cover and Watermark 2 image at gain= 0.7

Table 4.3: NC performance of the proposed method for different attacks at gain = 0.7

SN	Attack	NC(without Fuzzy logic)		NC(with Fuzzy logic)	
		W1	W2	W1	W2
1	Salt and paper(density 0.05)	0.4717	0.5821	0.7841	0.8208
2	Salt and paper(density 0.03)	0.4147	0.5198	0.7316	0.8311
3	Salt and paper(density 0.02)	0.4013	0.5013	0.7390	0.8387
4	Gaussian(mean=0, variance=1)	0.4885	0.5021	0.7556	0.8545
5	Rotation 90	0.5432	0.5784	0.8492	0.8639
6	JPEG 60	0.4253	0.5612	0.7139	0.7954
7	JPEG 30	0.4195	0.5367	0.7395	0.7977
8	JPEG 10	0.4124	0.5241	0.7582	0.8190
9	Resize	0.4765	0.5495	0.7374	0.7842

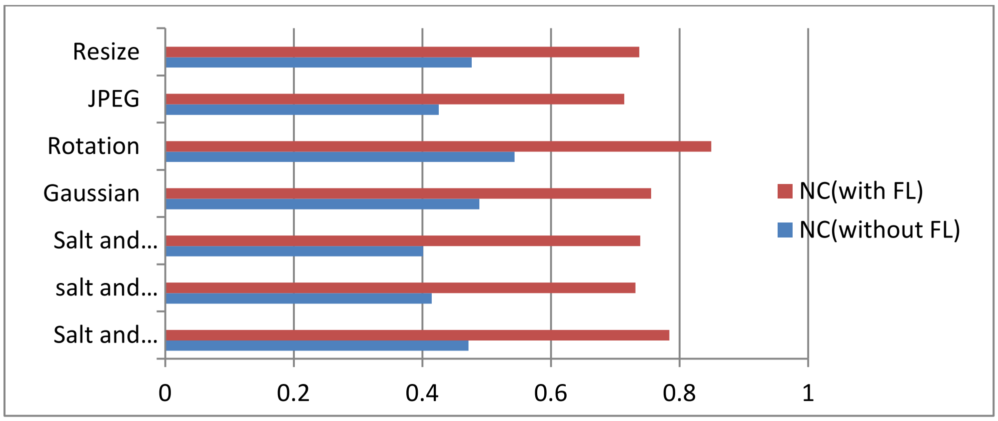


FIGURE 4.7: NC performance based on different attacks at gain= 0.7.

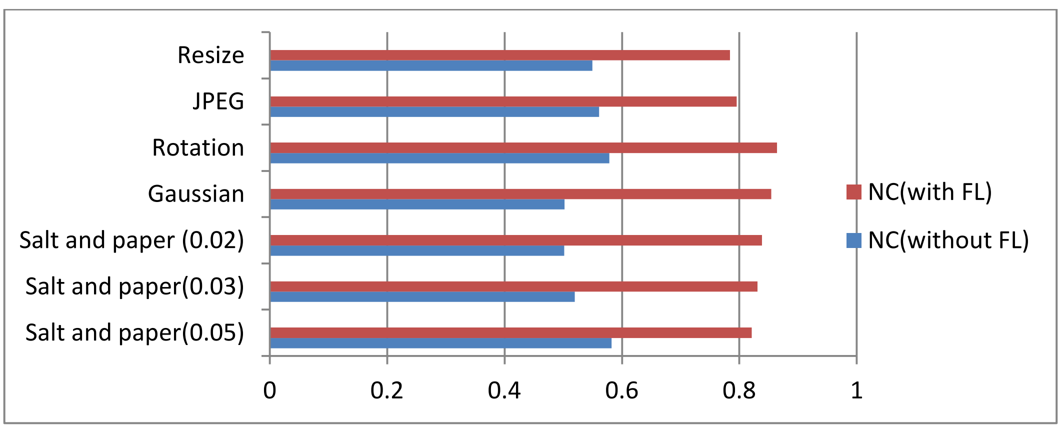


FIGURE 4.8: NC performance based on different attacks at gain= 0.7.

Table 4.4 to Table 4.6 represents the comparison of HL and HH sub bands .Table 4.4 shows the values of PSNR and NC without using attacks with different gain factors. The maximum NC value without using attacks with different gain factors. The maximum NC value without using Fuzzy logic is 0.8971 and 0.9247 and with Fuzzy logic is 0.9432 and 0.9662 at gain factor 0.7.

Table4.4: PSNR and NC performance of the proposed method at different gain

SN	GAIN FACTOR	PSNR(db)	NC(without Fuzzy logic)		NC(with Fuzzy logic)	
1	0.1	46.98	0.8645	0.8892	0.9221	0.9494
2	0.3	45.81	0.8705	0.9024	0.9308	0.9510
3	0.5	45.04	0.8773	0.9160	0.9372	0.9504
4	0.7	44.38	0.8847	0.9247	0.9432	0.9662

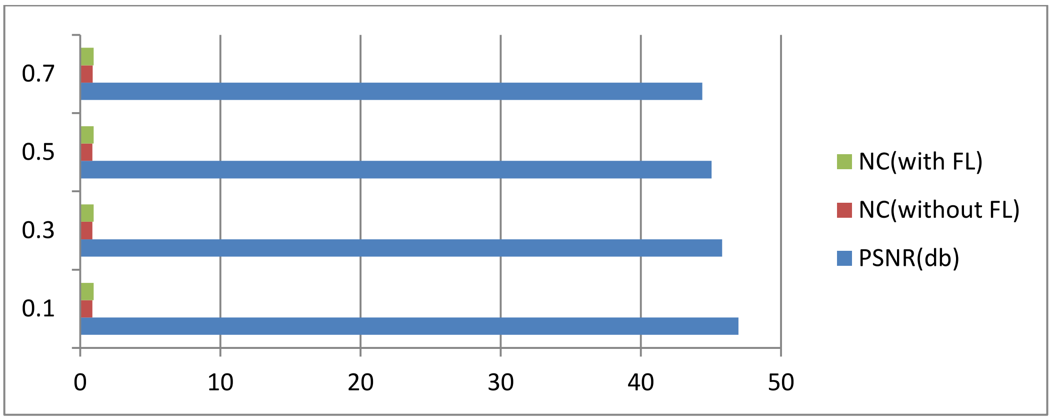


FIGURE 4.9: PSNR and NC performance of watermark1 at different gain

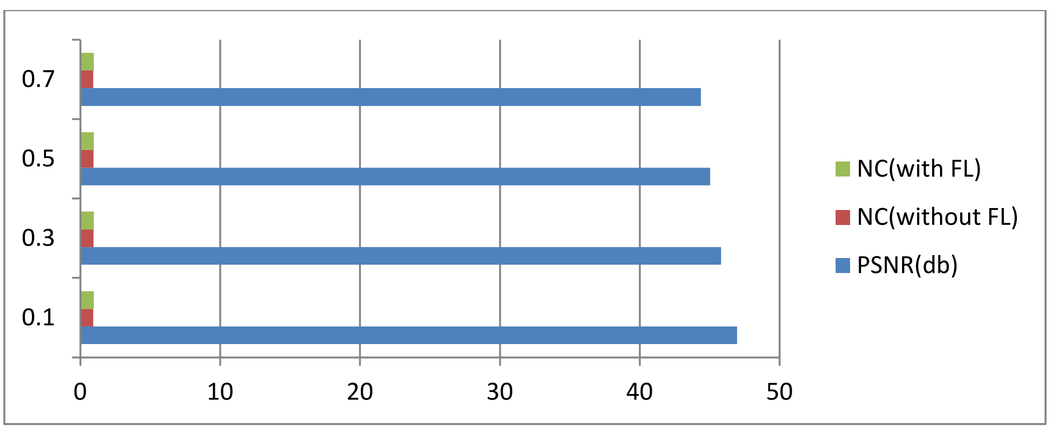


FIGURE 4.10: PSNR and NC performance of watermark2 at different gain

The Figure 4.9 and Figure 4.10 show the PSNR and NC performance values with different gain factor. In Table 4.5, the method shows the PSNR and NC value with different size of cover and watermark images. According to the different size of images the level of DWT also varies. In Table 4.6, it represents the performance with different attacks on the image.

It shows the robustness of the method when different attacks applied on the image. These three tables contain the values which are measured in HH and HL sub bands. Figure 4.11 and Figure 4.12 shows the NC and PSNR performance for different size of cover and watermark 1 image at gain= 0.7.

Table4.5: NC and PSNR performance for different size of cover and watermark image at gain = 0.7

SN	Cover Image	Watermark Image	Cover image size	Watermark image size	PSNR(db)	NC(without using fuzzy logic)		NC(using Fuzzy logic)	
						W1	W2	W1	W2
1	Butterfly	W1,W2	512×512	512×512	47.96	0.8356	0.8653	0.9076	0.9289
2	Flowers	W1,W2	256×256	32×32	47.68	0.8278	0.8610	0.8971	0.9202
3	Houses	W1,W2	128×128	16×16	46.91	0.8187	0.8411	0.8879	0.9156
4	Lotus	W1,W2	512×512	64×64	44.53	0.8112	0.8382	0.8841	0.8962
5	Lena	W1,W2	128×128	64×64	45.24	0.8167	0.8349	0.8738	0.8994
6	Earth	W1,W2	256×256	64×64	45.98	0.8219	0.8492	0.8791	0.9097

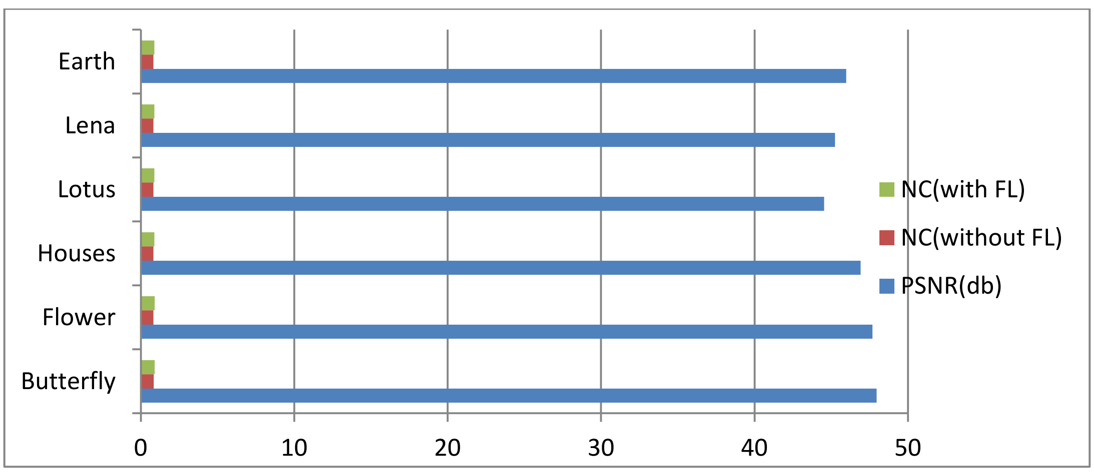


FIGURE 4.11: NC and PSNR performance for different size of cover and watermark 1 Image at gain=0.7

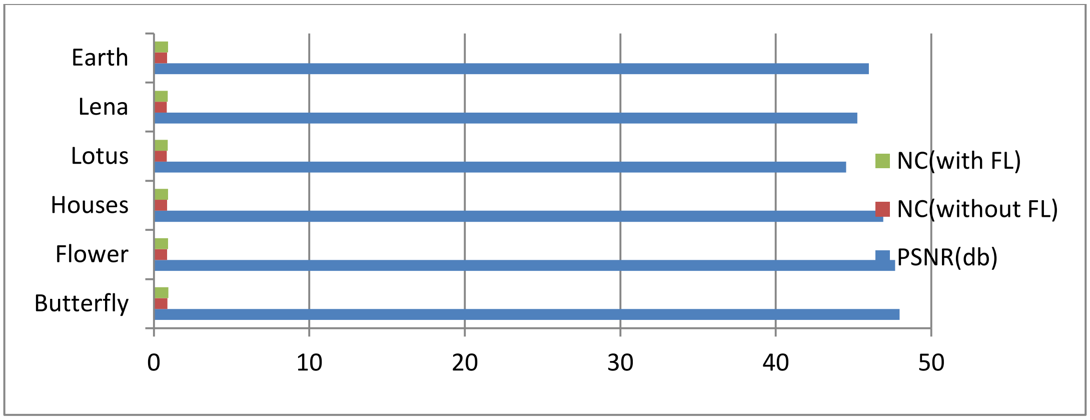


FIGURE 4.12: NC and PSNR performance for different size of cover and watermark 1 Image at gain=0.7

Table4.6: NC performance of the proposed method for different attacks at gain = 0.7

SN	Attack	NC(without Fuzzy logic)		NC(with Fuzzy logic)	
		W1	W2	W1	W2
1	Salt and paper(density 0.05)	0.4817	0.5021	0.7398	0.8389
2	Salt and paper(density 0.03)	0.4698	0.5198	0.7241	0.8376
3	Salt and paper(density 0.02)	0.4582	0.5313	0.7143	0.8309
4	Gaussian(mean=0, variance=1)	0.4129	0.5081	0.7457	0.8476
5	Rotation 90	0.5291	0.5724	0.8292	0.8458
6	JPEG 60	0.4287	0.5022	0.7230	0.8021
7	JPEG 30	0.4195	0.5367	0.7965	0.7954
8	JPEG 10	0.4124	0.5241	0.7821	0.7977
9	Resize	0.4765	0.5495	0.7354	0.7722

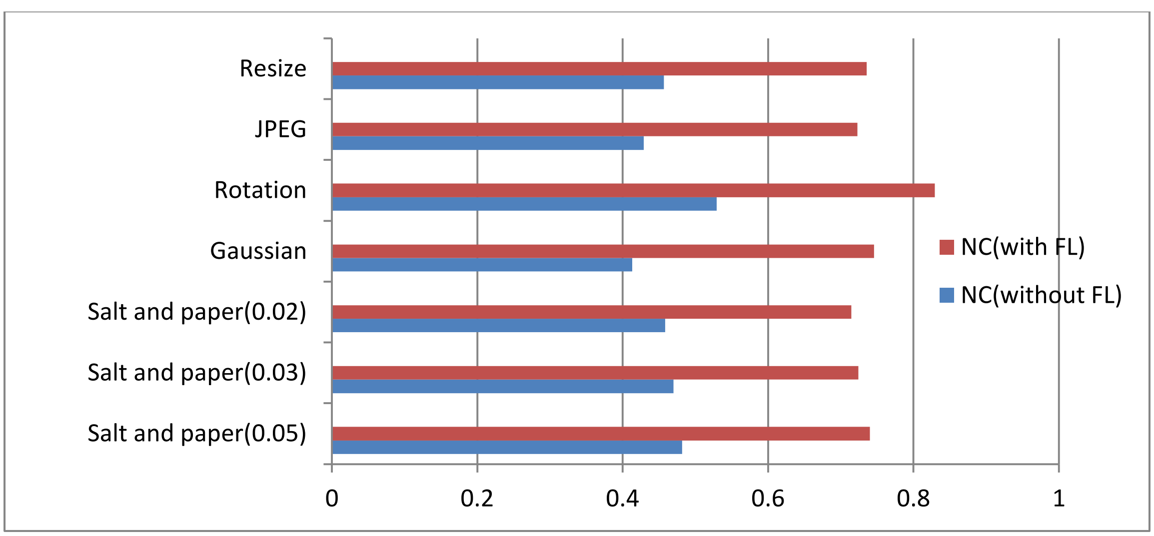


FIGURE 4.13: NC performance of method for different attacks at gain= 0.7

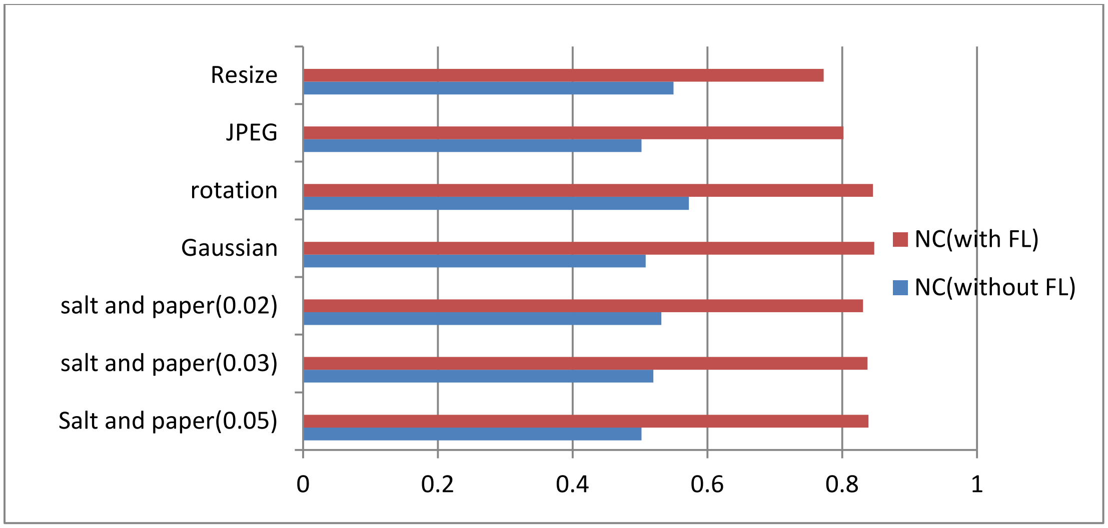


FIGURE 4.14: NC performance of method for different attacks at gain= 0.7

Table4.7: PSNR and NC performance of the proposed method at different gain

SN	GAIN FACTOR	PSNR(db)	NC(without Fuzzy logic)		NC(with Fuzzy logic)	
1	0.1	49.87	0.8727	0.9032	0.9321	0.9594
2	0.3	49.11	0.8832	0.9158	0.9408	0.9610
3	0.5	47.94	0.8981	0.9210	0.9472	0.9604
4	0.7	46.98	0.9051	0.9426	0.9532	0.9789

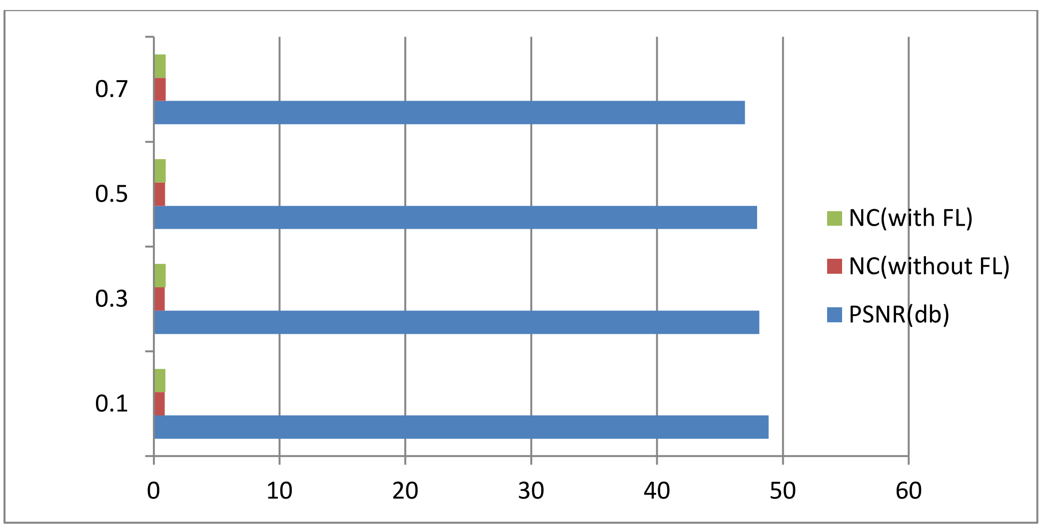


Figure 4.15: PSNR and NC performance without using attacks with different gain factors

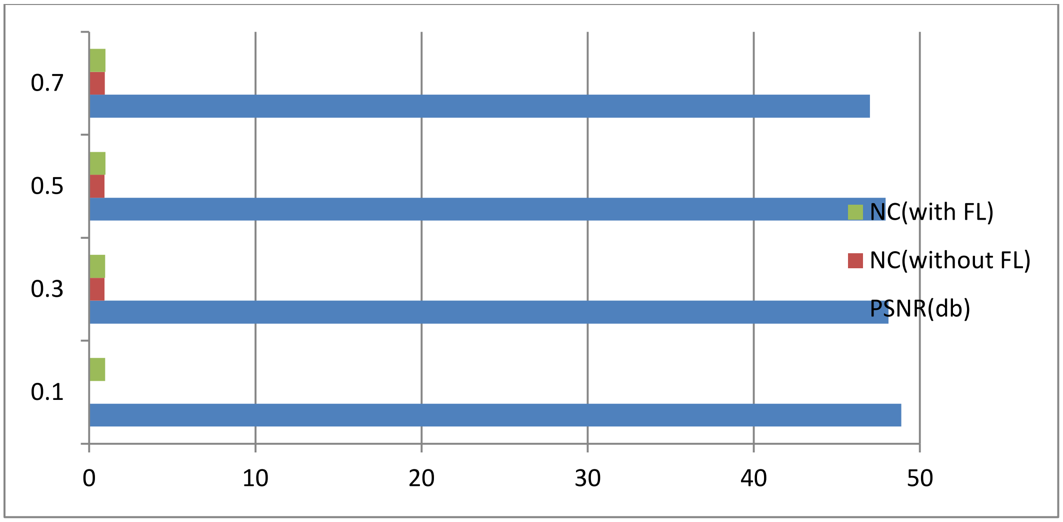


Figure 4.16: PSNR and NC performance without using attacks with different gain factors

Figure 4.13 and Figure 4.14 represents the NC performance of the method for different attacks at gain = 0.7 respectively. Table 4.7 to Table 4.9 it shows the comparison of LL and HL sub band. Table 4.7 represents the values of PSNR and NC without using attacks with different gain factors. The maximum NC value without using Fuzzy logic is 0.9051 and 0.9426 and with Fuzzy logic is 0.9532 and 0.9789 at gain factor 0.7. Figure 4.15 and Figure 4.16 represents the values of PSNR and NC without using attacks with different gain factors.

Table 4.8: NC and PSNR performance for different size of cover and watermark image at gain = 0.7

SN	Cover Image	Watermark Image	Cover image size	Watermark image size	PSNR(db)	NC(without using fuzzy logic)		NC(using Fuzzy logic)	
						W1	W2	W1	W2
1	Butterfly	W1,W2	512×512	512×512	48.96	0.8478	0.8862	0.9176	0.9438
2	Flowers	W1,W2	256×256	32×32	46.13	0.8308	0.8570	0.9086	0.9341
3	Houses	W1,W2	128×128	16×16	45.48	0.8197	0.8528	0.8991	0.9308
4	Flower	W1,W2	512×512	64×64	44.91	0.8042	0.8472	0.8798	0.9253
5	Lena	W1,W2	128×128	64×64	45.92	0.8217	0.8549	0.8839	0.9087
6	Earth	W1,W2	256×256	64×64	46.64	0.8239	0.8692	0.8976	0.9385

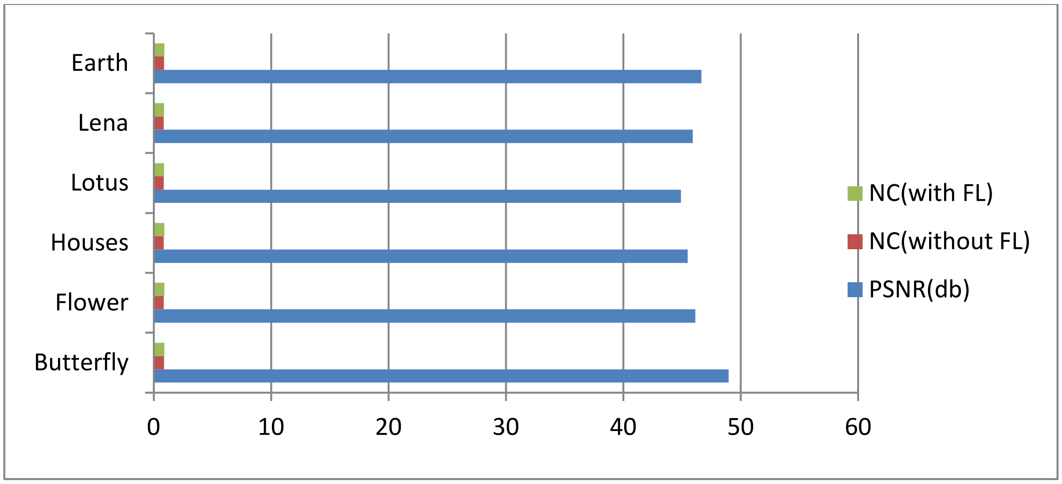


Figure 4.17: PSNR and NC value with different size of cover and watermark images.

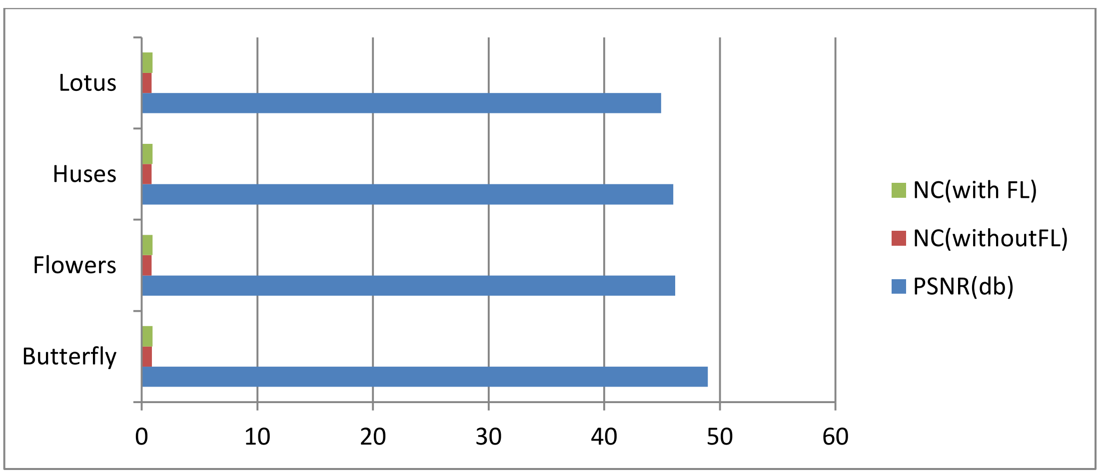


Figure 4.18: PSNR and NC value with different size of cover and watermark images.

In Table 4.8, the method shows the PSNR and NC value with different size of cover and watermark images. According to the different size of images the level of DWT also varies. Figure 4.17 and Figure 4.18 method shows the PSNR and NC value with different size of cover and watermark images. In Table 4.9, it represents the NC performance with different attacks on the image. It shows the robustness of the method when different attacks applied on the image. These three tables contain the values which are measured in LL and HL sub bands. Figure 4.19 and Figure 4.20 represents the NC performance with different attacks on the image. It shows the robustness of the method when different attacks applied on the image.

Table4.9: NC performance of the proposed method for different attacks at gain = 0.7

SN	Attack	NC(without Fuzzy logic)		NC(with Fuzzy logic)	
		W1	**W2**	**W1**	**W2**
1	Salt and paper(density 0.05)	0.4917	0.5121	0.7398	0.8489
2	Salt and paper(density 0.03)	0.4648	0.5198	0.7241	0.8376
3	Salt and paper(density 0.02)	0.4502	0.5378	0.7143	0.8309
4	Gaussian(mean=0, variance=1)	0.4192	0.5181	0.7457	0.8476
5	Rotation 90	0.5391	0.5645	0.8292	0.8458
6	JPEG 60	0.4287	0.5182	0.7230	0.7844
7	JPEG 30	0.4195	0.5277	0.7465	0.7957
8	JPEG 10	0.4124	0.5241	0.7681	0.8021
9	Resize	0.4765	0.5495	0.7374	0.7924

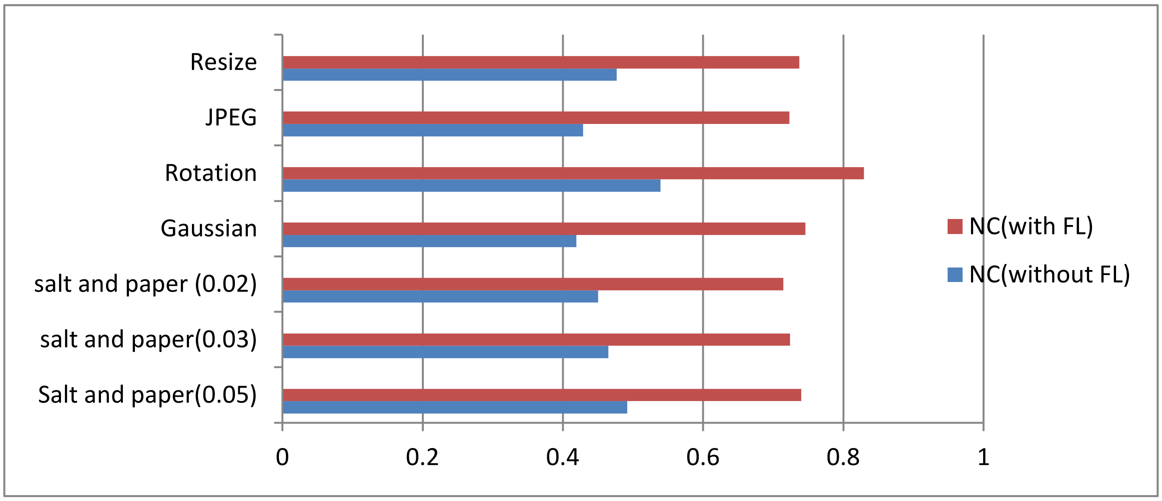


Figure 4.19: NC value with different attacks on images

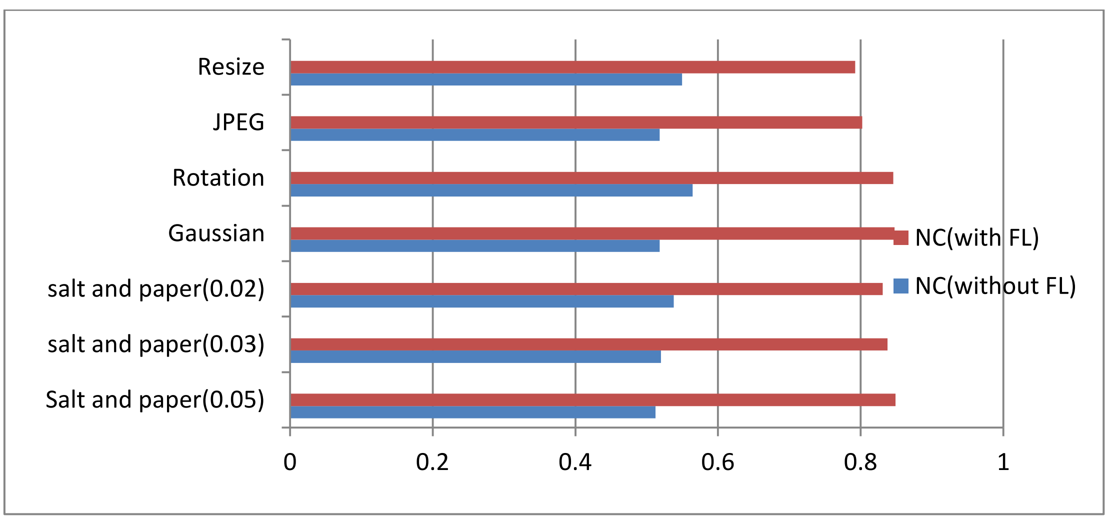


Figure 4.20: NC value with different attacks on images

4.4 CONCLUSION

In this paper, a hybrid technique based on DWT, DCT and SVD with Fuzzy logic is used. DWT is used because of its localized properties which are suitable for finding area in the cover image where watermark can be embedded. In case DCT, it improves resistance to attacks on the watermark and implicit visual masking utilizing the time-frequency localization property and gives a robust definition for the threshold which validates the watermark. One of attractive mathematical properties of SVD is that slight variations of singular values do not affect the visual perception of the cover image, which motivates the watermark embedding procedure to achieve better performance in terms of imperceptibility, robustness and capacity. In this method, multiple watermarking is applied to different sub bands i.e. LL & LH, HL &HH and LL &HL to improve the robustness.

Chapter 5
Conclusion and Scope for Future Work

The major benchmark parameters such as imperceptibility, robustness and capacity are considered in the proposed watermarking methods. The watermarking in transform domain techniques exploits the spatial and frequency information of the transformed data in multiple resolutions to gain robustness. The performance of the proposed watermarking methods highly depends on embedding and extraction process of the watermark, gain factors, noise variations and size of the watermark.

In this thesis**,** basic concepts about data hiding techniques, approaches, characteristics and applications of watermarks are presented in chapter 1. The chapter also presents the watermarking techniques in spatial domain and transform domain along with performance measure parameters. Further, important machine learning techniques are discussed in brief.

Chapter 2 presents the brief literature survey of the existing watermarking techniques using machine learning. The PSNR, NC performance of the reported techniques are also compared.

The DWT and Fuzzy logic based watermarking technique using digital image is proposed in **Chapter 3**. The performance of the proposed method is extensively evaluated with different gain factors, signal processing attacks, different size of cover image and watermark image. Refereeing table 3.1 it is evident that the Fuzzy logic based proposed method improved the NC values over the method without using Fuzzy logic. In this table, the NC values with Fuzzy logic have been obtained in the range from 0.48 to 0.91 and PSNR values in the range 52.97dB to 59.47dB. However, the NC values without Fuzzy logic have been obtained in the range from 0.059 to 0.75. Moreover, Table 3.3 shows the method is robust for different attacks.

Chapter 4 presents the grayscale multiple watermarking methods using fusion of DWT, DCT and SVD with Fuzzy logic. The performance of the proposed method is extensively evaluated with different gain factors, different size of cover image, watermark image and different DWT sub-bands. In addition, the performance of the method is also evaluated for different known attacks.

The performance of the method is extensively tested for

Referring Table 4.1 it shows the performance of the proposed method using LL and LH DWT sub-bands for embedding. In this case, the NC values with Fuzzy logic have been obtained in the range from 0.94 to 0.98 for LL DWT sub-bands and 0.93 to 0.95 for LH sub-band. The visual quality of the watermarked image is evaluated by PSNR and its value has been obtained in the range from 45.78dB to 47.28dB. However, the NC values without Fuzzy logic have been obtained in the range from 0.89 to 0.93 & 0.86 to 0.88 respectively.

Further, Referring to Table 4.4 it is established that the NC values with Fuzzy logic have been obtained in the range from 0.94 to 0.96 HL sub-band and 0.92 to 0.94 for HH sub-band of DWT. The PSNR values in the range 44.38 dB to 46.98 dB. However, the NC values without Fuzzy logic for HL and HH sub-band have been obtained in the range from 0.88 to 0.92 and 0.86 to 0.88 respectively.

Referring Table 4.7 it shows the performance of the proposed method using LL and HL DWT sub-bands for embedding. In this case, the NC values with Fuzzy logic have been obtained in the range from 0.95 to 0.97 for LL sub-band and 0.93 to 0.95 for HL sub-band. The PSNR values in the range 46.38dB to 49.98dB. However, the NC values without Fuzzy logic have been obtained in the range from 0.90 to 0.94 for LL sub-band and 0.87 to 0.90 for HL sub-band. In addition, the robustness performance (evaluated by NC values) of the proposed method is extensively evaluated for important signal processing attacks which includes rotation, Resize, Gaussian noise, JPEG compression.

The proposed techniques have improved the robustness of the watermarks using fuzzy logic with acceptable performance of the visual quality of the watermarked image which are the prime objectives of the research. However, it may have increased the computational complexity to some extent which needs to be investigated separately. Also, it may be desirable to investigate the performance of the watermarking methods that use some new transform, machine learning techniques, biometrics, different colour space model, video and audio watermarking etc.

RESEARCH PUBLICATIONS

1. Swati Sharma, Amit Kumar Singh and Pardeep Kumar, "Digital Image Watermarking Using Machine Learning Techniques: A Technical Review", The Sixth International Joint Conference on Advances in Engineering and Technology, Dec 12-13, 2015, NCR-Delhi region, India**.(Accepted)**
2. Swati Sharma, "Robust Digital Image Watermarking Scheme using Fuzzy Logic", Fourth International Conference on Parallel, Distributed and Grid Computing (PDGC).(On Review)

References

1. Cheddad, J. Condell, K. Curran and P. McKevitt, “Digital Image Steganography : Survey and Analyses of Current Methods”, Signal Processing, Vol.90, No.3, 2010.
2. Chu-Hsing Lin, Jung-Chun Liu, Chih-Hsiong Shih and Yan-Wei Lee, “A Robust Watermark Scheme for Copyright Protection,” International Conference on Multimedia and Ubiquitous Engineering, 2008
3. Prabhishek Singh and R S Chadha , “A Survey of Digital Watermarking Techniques, Applications and Attacks,” International Journal of Engineering and Innovative Technology, Vol. 2, No. 9, 2013.
4. Henri Bruno Razafindradina and Attoumani Mohamed Karim, “Blind and Robust Image Watermarking based on Wavelet and Edge Insertion,” International Journal on Cryptography and Information Security , Vol. 3, No.3, 2013.
5. Babak Mahdian and Stanislav Saic, “A bibliography on blind methods for identifying image forgery”, Signal Processing: Image Communication 25, 2010.
6. Huang-Chi Chen, Yu-Wen Chang and Rey-Chue Hwang, “A Watermarking Technique based on the Frequency Domain ”, Journal of Multimedia,Vol.7, No.1, 2012.
7. Roli Bansal, Priti Sehgal and Punam Bedi, “Securing fingerprint images using Hybrid Technique,”2012
8. Preeti Parashar and Rajeev Kumar Singh, “A Survey: Digital Image Watermarking Techniques”, International Journal of Signal Processing, Image Processing and Pattern Recognition, Vol. 7, No. 6,2014.
9. Harshita rawat, Ashwani kumar and Satendra kumar, “Robust Digital Image Watermarking Scheme for Copyright Protection,” International Journal of Computer Applications, Vol.75 ,No. 18, 2013.
10. Jih Pin Yeh, Che-Wei Lu, Hwei-Jen Lin, and Hung-Hsuan Wu, “Watermarking technique based on DWT associated with embedding rule, “International Journal of Circuit, System and Signal Processing, Vol.4, No. 2, 2010.
11. Mayank Vatsa, Richa Singh and Afzal Noore, “Improving biometric recognition accuracy and robustness using DWT and SVM watermarking”, IEICE Electronics Express, Vol.2, 2005.
12. Kaiser J.Giri, Mushtaq Ahmad Peer and P. Nagabhushan, “A Robust Color Image Watermarking Scheme Using Discrete Wavelet Transform,” International Journal of Image Graphics, Vol. 1, pp. 47-52, 2015.

13. B.Jagadeesh , P.Rajesh Kumar and P.Chenna Reddy, " Digital Image Watermark Extraction in Discrete Wavelet Transform Domain using Support Vector Machine,"ACEEE International Journal of Recent Trends in Engineering and Technology ,Vol.11,2014
14. Yogendra Kumar Jain and Saurabh Tiwari, "An Enhanced Digital Watermarking for Color Image using SVM," International Journal of Computer Science and Information Technology, Vol.2, No. 5, 2011
15. Vaishali S. Jabade and Dr. Sachin R. Gengaje, "Literature Review of Wavelet Based Digital Image Watermarking Techniques", International Journal of Computer Applications, Vol.31, No.1, 2011.
16. Simon Tong and Edward Chang, "support Vector Machine Active Learning for Image Retrieval," ACM, 2001
17. Shwu-Huey Yen and Chia-Jen Wang, "SVM Based watermarking technique," Tamkang Journal of Science and Engineering, Vol. 9, No. 2, 2006
18. Ramandeep Singh , "Digital Image Watermarking: An Overview". International Journal of Research (IJR), Vol. 2, No. 05, pp. 1087-1094, 2015.
19. Wu Jianzhen, "A RST Invariant Watermarking Scheme Utilizing Support Vector Machine and Image Moments for Synchronization," IEEE International Conference on Information Assurance and Security, 2009
20. Saadiah Yahya, Hanizan Shaker Hussain and Fakariah Hani M. Ali, "DCT Domain Stega SVM-shifted LSB Model for highly Imperceptible and robust cover image," International Conference on Computing and Informatics, Vol.43, 2015
21. Bhupendra Ram, "Digital Image Watermarking Technique Using Discrete Wavelet Transform and Discrete Cosine Transform," IEEE International Journal of Advancements in Research & Technology, Vol.2, 2013.
22. K. Deb, Md. S. Al-Seraj, Md. M. Hoque and Md. I. H. Sarkar , "Combined DWT-DCT Based Digital Image Watermarking Technique for Copyright Protection", International Conference on Electrical and Computer Engineering, pp. 20-22, 2012.
23. Chandan Saha, Md. Foisal Hossain and B. M. Shahnewaz Abdullah, "Improving the Security of Spatial Domain based Digital Image Watermarking using Chaotic Map and Cellular Automation", International Journal of Graphics and Signal Processing, 2016.
24. B.Jagadeesh , P.Rajesh Kumar and P.Chenna Reddy, "Robust Digital Image Watermarking Scheme in Discrete Wavelet Transform Domain using Support Vector Machine," International Journal of Computer Applications, Vol.73, No. 14,2013

25. Navdeep Goel and Gurwinder Singh, "Study of Wavelet Functions of Discrete Wavelet Transformation in Image Watermarking", International Journal of Engineering Science, Vol. 17, 2016.
26. Maklachur Rehman, "A DWT, DCT and SVD based Watermarking Technique to protect the Image Piracy", International Journal of Managing Public Sector Information and Communication Technologies, Vol. 4, No. 2, 2013.
27. Erkan Yavuz and Ziya Telatar, "Improved SVD-DWT Based Digital Image Watermarking Against Watermark Ambiguity," 2007.
28. Hongqin Shi, Fangliang Lvi and Yiqin Cao, "A Blind Watermarking Technique for Color Image based on SVD with Circulation," Journal of Software, Vol.9, No. 7, 2014.
29. Emir Ganic and Ahmet M. Eskicioglu, "Robust DWT-SVD Domain Image Watermarking: Embedding Data in All Frequencies", Workshop on Multimedia and Security, ACM , pp. 166-174, 2004.
30. T. Sridevi and S Sameena Fatima, "Digital Image Watermarking using Fuzzy Logic approach based on DWT and SVD," International Journal of Computer Applications, Vol. 74, No.13, 2013.
31. Tri Wijayanti Septiarini, Agus Maman Abadi, and Muhammad Rifki Taufik, " Applications of Wavelet Fuzzy Model to forecast the exchange rate IDR of USD", International Journal of Modeling and Optimization, Vol. 6, No. 1, 2016
32. Chih-Chin Lai, "A digital watermarking scheme based on singular value decomposition and tiny genetic algorithm," Digital Signal Processing, Vol.21, 2011
33. Le Hoang Thai, Tran Son Hai and Nguyen Thanh Thuy, "Image Classification using Support vector machine and Artificial neural networks," International Journal of Information Technology and Computer Science, Vol.32, No. 38, 2012
34. Vafaei, H. Mahdavi-Nasab and H. Pourghassem, "A new blind Robust Watermarking method based on Neural Networks in Wavelet Transform Domain, " World Applied Science Journal, Vol. 22, No. 11, 2013.
35. Zhenghao Shi and Lifeng He, "Application of neural network in medical Image Processing," International Symposium on Networking and Network Security, 2010
36. Fan Zhang and Hongbin Zhang, "Image watermarking capacity using Neural Network," IEEE International Conference of Web Intelligence, 2004
37. M. Gowrishankar, P. Nagaveni and P. Balakrishnan, "Transmission Line Fault Detection and Classification Using Discrete Wavelet Transform and Artificial Neural Network", Middle-East Journal of Scientific Research, Vol. 24, No. 4, 2016

38. Tarun Mahashwari, Amit Asthana, "Image Enhancement Using Fuzzy Technique," International Journal of Research Review in Engineering Science and Technology, Vol.2, No.2, 2013.
39. Nallagarla Ramamurthy and Dr. S.Varadarajan, "Robust Digital image watermarking scheme with Neural Network and fuzzy logic approach," International Journal of Emerging Technology and Advanced Engineering, Vol.2, No. 9, 2012.
40. N. Palanivel and S. Gokulavani, "Fuzzy Based Scaling Rotational and Transformation for Invariant Texture Classification", International Journal of Signal Processing, Image Processing and Pattern Recognition ,Vol.9, No.2, pp.71-78, 2016
41. M.Pitchammal, S. Shajun Nisha, and Dr. M.Mohammad Sathik, "Noise Reduction in MRI Neck Image Using Adaptive Fuzzy Filter in Contourlet Transform", International Journal of Engineering Science and Computing, Vol. 6, No. 3, 2016
42. Yu, Lean, Shouyang Wang and Kin Keung Lai, "An Intelligent-Agent-Based Fuzzy Group Decision-Making Model for Financial Multicriteria Decision Support: The Case of Credit Scoring," European Journal of Operational Research, Vol.195, No. 3, 2009.
43. Swathy Nair, Bindu Elias and VPS Naidu, "Image fusion using Type-2 Fuzzy Systems", International Journal of Advanced Reseach Electrical, Electronics and Instrumentation Engineering, Vol. 3, No. 5, 2014
44. Abdallah A. Alshennawy, and Ayman A. Aly, "Edge detection in digital images using fuzzy logic technique", International Journal of Electrical and Computer Engineering, Vol. 4, No.7, 2009
45. Arshdeep Kaur and Amrit Kaur, "Comparison of Mamdani- type and Sugeno-Type Fuzzy Inference System for Air conditioning System", International Journal of Soft Computing and Engineering, Vol. 2, No. 2, 2012.
46. Gwanggil Jeon, "Histogram based color Image Transformation using fuzzy Membership function," International Journal of Software Engineering and aapllications, Vol.8, No.5. pp.63-72, 2014.
47. Mandeep Singh Sandhu , Vikram Mutneja and .Nishi, "Image edge Detection by using Rule Based Fuzzy Classifier", International Journal of Computer Science and Information Technologies, Vol. 2, No. 5, 2011.
48. Liuping Feng, Dongsheng Cong, Hou Shu, and Ben Liu, "Adaptive Halftone Watermarking Algorithm Based on Particle Swarm Optimization," Journal of Multimedia, Vol.8, No. 3, 2013.
49. Dr. Pankaj Mohindru, Maninder Singh Gill and Dr. Pooja, "A New Image Fusion Algorithm Based on Wavelet Transform and Adaptive Neuro Fuzzy Logic Approach", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3, No. 8, 2014

50. Lei Li , Wen-Yan Ding and Jin-Yan Li, "A Novel Robustness Image Watermarking Scheme Based on Fuzzy Support Vector Machine," IEEE Pattern Recognition and Intelligence System,2010.
51. Srinivasa Rao Dammavalam, Seetha Maddala2 and Krishna Prasad, "Quality Assessment of Pixel level Image fusion using Fuzzy Logic", International Journal on Soft Computing, Vol.3, No.1,2012.
52. Pankaj U. Lande, Sanjay N Talbar and G.N. Shinde, "Robust Image Adaptive Watermarking using Fuzzy logic at EPGA report", International Journal of Signal Processing, Image Processing and Pattern Recognition, Vol. 3, No. 4, 2010.
53. Preeti Banerjee and Deepak Kumar, "Designing and Implementation of Efficient Fuzzy Logic Based Fractal Image Compression Technique in DCT Domain Using Quadtree Algorithm", International Journal of Computer Science and Information Technologies, Vol. 5, No. 3 , 2014, 3494-3499.
54. Neha Pandey, Himani Agrawal, " Hybrid Image Compression Based On Fuzzy Logic Technology", International Journal of Science, Engineering and Technology Research, Vol. 3, No. 9, 2014
55. Amrita Sarkar, G.Sahoo and U.C.Sahoo, "Applications of Fuzzy Logic in Transport Planning", International Journal on Soft Computing , Vol.3, No.2, 2012