

# A Novel Approach for Digital Image Watermarking



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Under the Supervision of

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## **Declaration**

We hereby declare that this thesis is based on results obtained from our own work. Due acknowledgement has been made in the text to all other material used. This thesis, neither in whole nor in part, has been previously submitted to any other University or Institute for the award of any degree or diploma.

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# Table of Contents

<b>Acknowledgement</b> .....	<b>ii</b>
<b>List of Figures</b> .....	<b>v</b>
<b>List of Tables</b> .....	<b>vi</b>
<b>List of Abbreviations</b> .....	<b>vii</b>
<b>Abstract</b> .....	<b>1</b>
<b>Chapter 1: Introduction</b> .....	<b>2</b>
1.1 Motivation.....	2
1.2 Contribution Summary.....	3
1.3 Thesis Outline.....	3
<b>Chapter 2: Background Analysis</b> .....	<b>4</b>
2.1 Digital Image Watermarking.....	4
2.1.1 An embedding Function.....	4
2.1.2 Attacking function.....	4
2.1.3 An extraction or detection function.....	5
2.1.4 Robustness.....	5
2.1.5 Imperceptibility.....	5
2.1.6 Image Segmentation.....	6
2.2 Discrete Wavelet Transform (DWT).....	6
2.2.1 Algorithm.....	8
2.3 Particle Swarm Optimization (PSO).....	8
2.3.1 Algorithm.....	10
2.3.2 Flowchart.....	11
2.4 Fuzzy C-means Clustering (FCM).....	12

2.4.1 Algorithm .....	13
2.4.2 Flowchart.....	14
2.5 XieBeni Index .....	15
<b>Chapter 3: Literature Review .....</b>	<b>16</b>
3.1 Previous works .....	16
3.2 Methodology .....	17
3.2.1 Data collection.....	17
3.2.2 Tools used.....	17
<b>Chapter 4: Proposed model.....</b>	<b>18</b>
4.1 System Design.....	18
4.2 Algorithm .....	20
4.3 Flowchart.....	21
<b>Chapter 5: Experimental Results .....</b>	<b>22</b>
<b>Chapter 6: Conclusion and Future Work.....</b>	<b>27</b>
6.1 Conclusion.....	27
6.2 Future work .....	27
<b>References .....</b>	<b>28</b>

## List of Figures

Fig. 2.1.1. Generic model of a digital image watermarking .....	4
Fig. 2.1.2. (a) (c) Watermarked Image [using DWT-SVD].....	5
Fig. 2.1.3. (b) (d) Extracted Watermark.....	6
Fig. 2.1.4. (a) host image (b) watermarked image .....	6
Fig. 2.2.1. 3-level DWT decomposition .....	7
Fig. 2.2.2. 2-level DWT decomposition of an image.....	7
Fig. 2.3.1. Swarm movement using PSO .....	9
Fig. 2.3.2. Standard PSO flowchart .....	11
Fig. 2.4.1 Standard FCM flowchart .....	14
Fig. 4.1.1 Block diagram of the proposed model.....	19
Fig. 4.3.1 Flowchart of the proposed model .....	21
Fig. 5.1 (a) Host image .....	23
Fig. 5.1 (b) Watermark image.....	23
Fig. 5.1 (c) Watermarked image .....	23

## List of Tables

TABLE I: Growth of Internet .....	2
TABLE II: Performance analysis of proposed model.....	23
TABLE III: MSE Values after various attacks .....	24
TABLE IV: Correlation coefficient values after JPEG compression .....	25
TABLE V: Correlation coefficient values after Re-watermarking.....	25
TABLE VI: Correlation Coefficient values after noise addition.....	26
TABLE VII: PSNR values after various attacks.....	26

## **List of Abbreviations**

2-D	Two Dimensional
CC	Correlation Coefficient
DWT	Discrete Wavelet Transform
FCM	Fuzzy C-Means Clustering
IDWT	Inverse Discrete Wavelet Transform
JPEG	Joint Photographic Experts Group
MSE	Mean Squared Error
PNG	Portable Network Graphics
PSNR	Peak-Signal-to-Noise-Ratio
PSO	Particle Swarm Optimization
RGB	Red, Blue, Green
SNR	Signal-to-Noise-Ratio



## **Abstract**

In this paper, a novel adaptive digital image watermarking model based on modified Fuzzy C-means clustering is proposed. For watermark embedding process, we used Discrete Wavelet Transform (DWT). A segmentation technique XieBeni integrated Fuzzy C-means clustering (XFCM) is used to identify the segments of original image to expose suitable locations for embedding watermark. We also pre-processed the host image using Particle Swarm Optimization (PSO) to lend a hand to the clustering process. The goal is to focus on proper segmentation of the image so that the embedded watermark can withstand common image processing attacks and provide security to digital images. Several attacks were performed on the watermarked images and original watermark was extracted. Performance measures like PSNR, MSE, CC were computed to test the extracted watermarks with and without attacks. Experimental results show that the proposed scheme has performed well in terms of imperceptibility and robustness when compared to other watermarking models.

# CHAPTER 01

## Introduction

With the rapid growth of Internet, distribution of digital information has become amplified. Most of the digital information are in the form of images, audio, video or text format. As a result, the transfer of data gives birth to prominent issues such as illegal copying, modifying, tampering and copyright protection. Digital Watermarking emerged as a solution for protecting the multimedia data. Its application is broad, including ownership protection, content authentication, side information conveyance and so on. Our aim is to develop a digital watermarking scheme which will not only embed the watermark efficiently but at the same time be robust to common image processing attacks such as cropping, rotation, noise addition, compression, etc. so that one may not tamper with the image.

### 1.1 Motivation

The usage of worldwide web (www) has increased drastically in the last decade, there is a significant rise from 16 % of the world's population (6.5 billion) in 2005 to a 40 % of the total population (7.2 billion) in 2014 with the growth being proportional to time. Therefore, communication and information transfer has also grown in turn, giving importance to protection of intellectual property rights.

TABLE I: Growth of Internet

	<b>2005</b>	<b>2010</b>	<b>2014</b>
<b>World population</b>	6.5 billion	6.9 billion	7.2 billion
<b>Not using the Internet</b>	84%	70%	60%
<b>Using the Internet</b>	16%	30%	40%
<b>Users in the developing world</b>	8%	21%	32%
<b>Users in the developed world</b>	51%	67%	78%

The term "Digital Watermark" was coined by Andrew Tirkel and Charles Osborne in December 1992. The first successful embedding and extraction of a stenographic spread spectrum watermark was demonstrated in 1993 by Andrew Tirkel, Charles Osborne and Gerard Rankin [1].

## **1.2 Contribution Summary**

Ever since then, a good number of models have been proposed by various researchers trying to come up with efficient digital watermarking schemes. However, most of them focused solely on the watermarking rather than the image segmentation. If the images are properly segmented, exposing the most suitable areas then the watermarking would be more competent. A competent watermarking model would stand strong against the image processing attacks. This gave us the incentive to conduct a research to combine image segmentation techniques with the most operational digital watermarking algorithm to propose a model that outperforms the existing ones.

## **1.3 Thesis Outline**

- Chapter 2 provides the Background study in details including the algorithms and techniques used in the system
- Chapter 3 discusses the Literature Review of related works in this field
- Chapter 4 describes the proposed model along with implementation details
- Chapter 5 presents the results of the experiment along with performance analysis and comparisons
- Chapter 6 concludes the paper specifying the limitations and challenges while planning future development of the project

# CHAPTER 02

## Background Analysis

### 2.1 Digital Image Watermarking

It is the process of adding multimedia information on an image in the form of text, image or logo for the purpose of owner identification and security. The information may or may not be visible.

Digital image watermarking algorithms are classified into three major categories:

- Spatial domain: The watermark is embedded directly into pixel values of the original image
- Transformation/Frequency domain: The watermark is embedded into transformed coefficients of the original image by using suitable transform.
- Hybrid domain: It is the combination of two or more frequency domain techniques

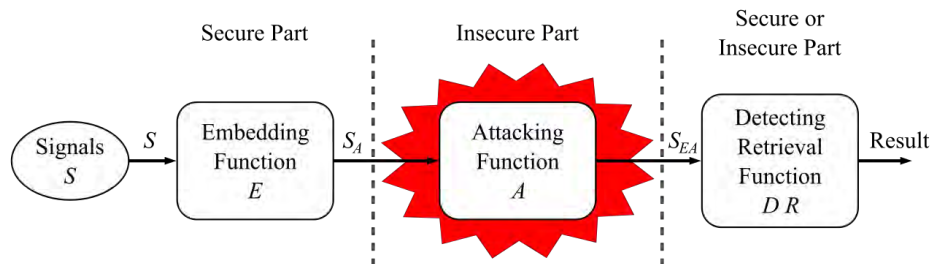


Fig. 2.1.1 Generic model of a digital image watermarking

The process of Digital Image Watermarking usually has three major portions.

#### 2.1.1 An embedding function

The process of where an algorithm accepts the host and the data to be embedded, and produces a watermarked signal.

### 2.1.2 Attacking function

The process of modifying the watermarked digital signal in different ways for example, compression of the data (in which resolution is diminished), cropping or rotating an image, or intentionally adding noise.

### 2.1.3 An extraction or detection function

The process of applying an algorithm to extract the watermark from the attacked image. In *robust* digital watermarking applications, the extraction algorithm should be able to produce the watermark correctly, even if the modifications were strong.

The properties of Digital Watermarking include retaining of the quality of the watermarked data and the detection of the watermark under different kinds of intentional or unintentional attacks i.e. the watermarking should be robust and imperceptible.

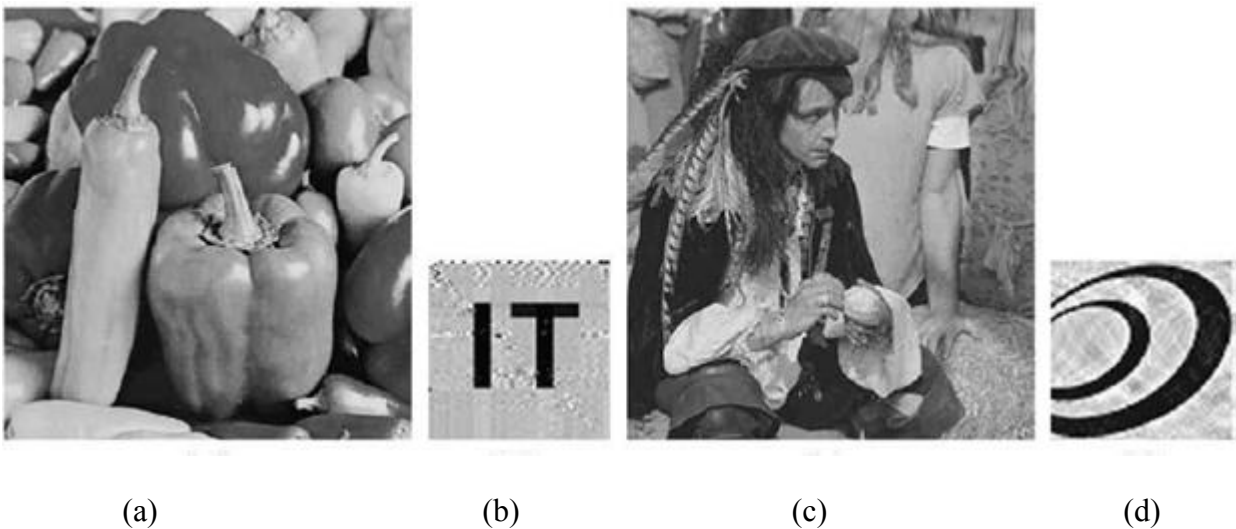


Fig. 2.1.2 (a) (c) Watermarked Image [using DWT-SVD] (b) (d) Extracted Watermark [2]

### 2.1.4 Robustness

Robustness is the ability to resist certain malicious attacks such as general image processing operations (cropping, filtering, compression, etc.).

### 2.1.5 Imperceptibility

Imperceptibility refers to invisible degradation of the host image when watermarked.

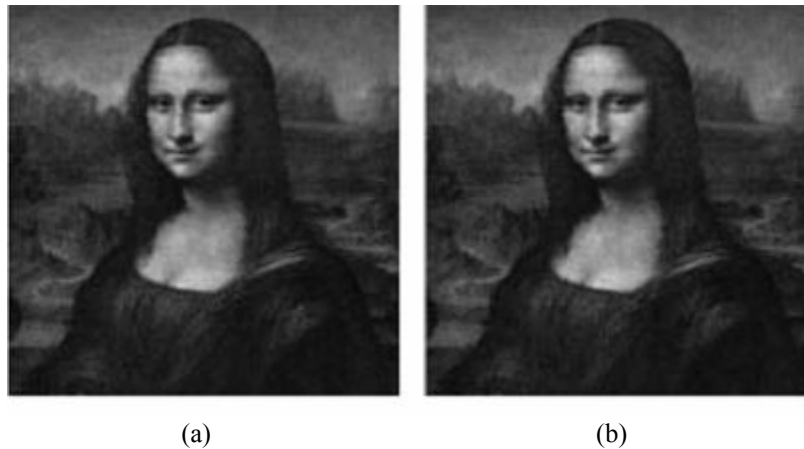


Fig. 2.1.3. (a) Host image (b) watermarked image [3]

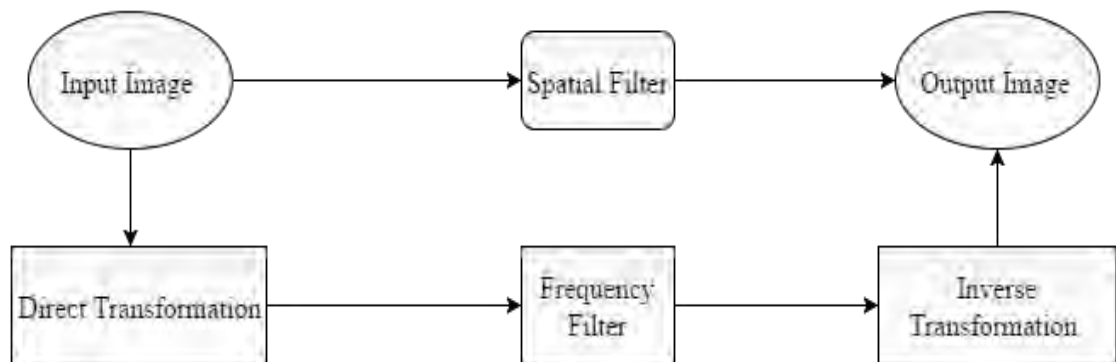


Fig. 2.1.4. Image processing structure in Spatial and Transform domains

The transform methods have proved to have greater robustness when tested against common attacks. Hence, we have worked with the transform domain in our research.

### 2.1.6 Image Segmentation

Image segmentation is the process of simplifying the representation of an image making it easier to analyze. In order to do so, a digital image is partitioned into multiple segments such as pixels, which may be grouped following certain rules. The goal is to form clusters or regions of elements which have similar characteristics, such as color, intensity or texture.

## 2.2 Discrete Wavelet Transform (DWT)

DWT is a mathematical implement for ordered decomposition of an image into a set of basis functions, known as wavelets. A wavelet is an oscillation with an initial amplitude of zero which increases momentarily and then decreases back to zero. Wavelets contain both frequency and location information, formed by translations and dilations of a mother function.

It is an efficient and easy tool to implement watermarking algorithm. The image is decomposed into frequency bands and the watermarking is done by modifying wavelet coefficients [4].

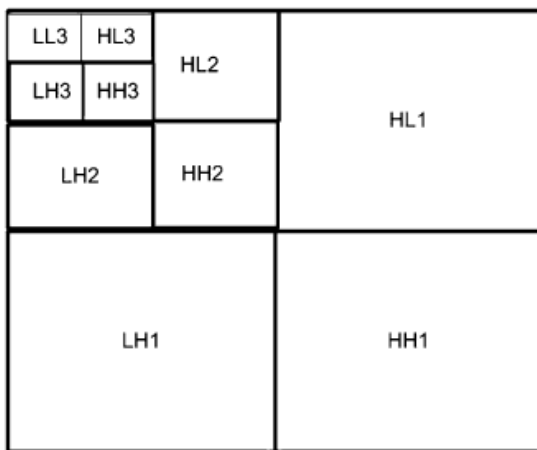


Fig. 2.2.1. 3-level DWT decomposition [3]

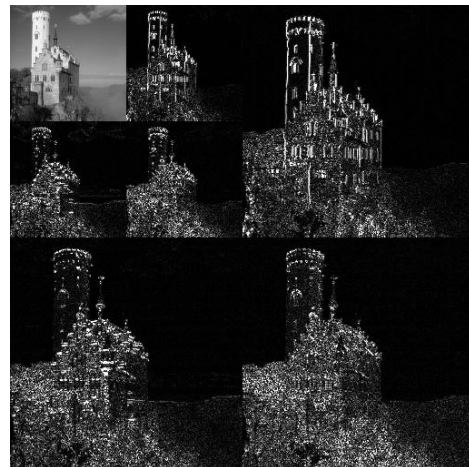


Fig. 2.2.2. 2-level DWT decomposition of an image

### 2.2.1 Algorithm

The following steps are used for watermark embedding and extraction using DWT:

1. Original host image is divided into 8x8 image blocks.
2. Two-level DWT transform decomposes the image into frequency sub-bands,  $LL_1$ ,  $LH_1$ ,  $HL_1$ ,  $HH_1$  block by block.  $HH_1$  is further decomposed to give  $LL_2$ ,  $LH_2$ ,  $HL_2$ ,  $HH_2$ .
3. The watermark image is processed using steps (1) and (2).
4. The high sub-band of second level DWT transform  $HH_2$  is selected to embed watermark image.
5. Watermark is embedded using the coefficient matrices with respect to a *haar* wavelet filter.
6. Apply Inverse Discrete Wavelet (IDWT) Transform to all the blocks to extract the watermark image from the watermarked image.

### 2.3 Particle Swarm Optimization (PSO)

PSO is a meta-heuristic swarm based algorithm proposed by Dr. Eberhart and Dr. Kennedy in 1995 [6]. It is basically established by following the social behavior of birds within a flock. In PSO, the potential solutions are called particles. Every particle has velocity  $V$ , position  $X$  and a fitness value. The particles fly through the problem space by following the current optimum particle which is measured by the  $p_{best}$  and  $g_{best}$  values [5, 7, 8].



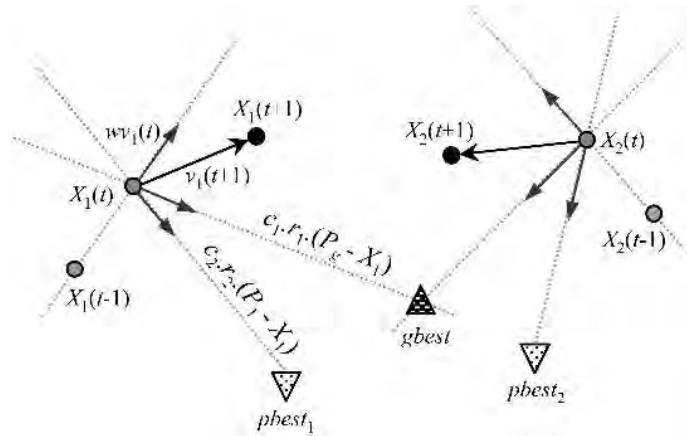


Fig. 2.3.1 Swarm movement using PSO

At first, PSO is initialized with a group of random particles,  $P$ . In every generation, each particle updates its velocity by two best values,  $p_{best}$  and  $g_{best}$  where  $p_{best}$  is the local optimum fitness of a particle and  $g_{best}$  is the global best fitness value in the swarm. The swarm progresses by scheming these two values [5, 7, 8].

After finding the local ( $p_{best}$ ) and global ( $g_{best}$ ) best values, the particle's velocity and position are updated by following equations:

$$V(t + 1) = w \cdot V(t) + c_1 r_1 (p_{best}(t) - X(t)) + c_2 r_2 (g_{best}(t) - X(t)) \quad (1)$$

$$X_{(t+1)} = X_{(t)} + V_{(t+1)} \quad (2)$$

Where,  $k = 1, 2, 3, \dots, P$ ;  $w$  is the inertia weight;  $c_1$  and  $c_2$  are positive acceleration coefficients;  $r_1$  and  $r_2$  are random values in range  $[0, 1]$ ;  $P$  is the total number of particles in the swarm [5, 8]. The detail procedure of PSO algorithm is depicted below:

### 2.3.1 Algorithm

*For each particle*

Initialize particle

*For each particle*

Calculate fitness value

If fitness value is better than best fitness value ( $p_{best}$ ) in history

Set current value as new  $p_{best}$

*End*

Choose the particle with the best fitness value among the swarm as  $g_{best}$

*For each particle*

Calculate particle Velocity using Eq. (1)

Update particle Position using Eq. (2)

*End*

*Continue while maximum iterations or minimum iteration criteria is met*

### 2.3.2 Flowchart

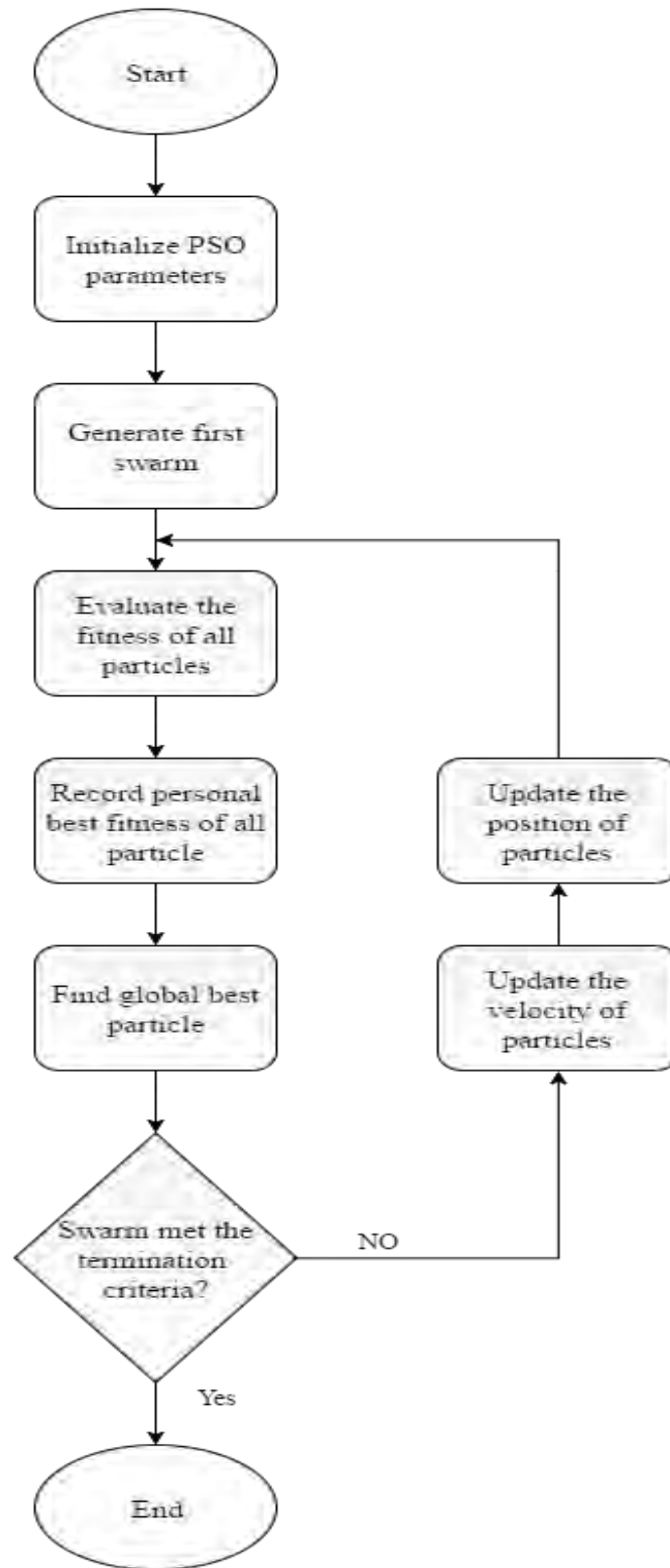


Fig. 2.3.2. Standard PSO flowchart

## 2.4 Fuzzy C-means Clustering (FCM)

Fuzzy C-means Clustering is a popular clustering algorithm introduced by Bezdek [4]. Clustering is the process of assigning data points into groups called clusters. Data points in the same cluster has similar features and dissimilar features when compared to different clusters [5].

A set of  $n$  data points  $p = \{p_1, p_2, \dots, p_n\}$  is divided into  $c$  clusters with  $s = \{s_1, s_2, \dots, s_n\}$  centroids. In FCM, every data point has a degree of relationship with each cluster known as membership value,  $\mu_{ij}$ . It is the value of  $j$ th data point in the  $i$ th cluster. The membership matrix,  $\mu$  has  $n$  rows and  $c$  columns. Euclidian distance between data point  $p_i$  and cluster center  $s_j$  is  $d_{ij}$ . The objective function,  $J_m$  must be minimized for proper clustering [5]. The following conditions must hold for the process:

$$\mu_{ij} \in [0,1] \quad \forall i=1,2,\dots,n; \quad \forall j=1,2,\dots,c \quad (3)$$

$$\sum_{j=1}^c (\mu_{ij}) = 1 \quad (4)$$

$$0 < \sum_{i=1}^n (\mu_{ij}) < n \quad (5)$$

$$J_m = \sum_{j=1}^c \sum_{i=1}^n \mu_{ij}^m d_{ij} \quad (6)$$

$$d_{ij} = || p_i - s_j || \quad (7)$$

Cluster center  $s_j$  is calculated by:

$$s_j = \frac{\sum_{i=1}^n \mu_{ij}^m p_i}{\sum_{i=1}^n \mu_{ij}^m} \quad (8)$$

Membership function  $\mu_{ij}$  is computed by:

$$\mu_{ij} = \frac{1}{\sum_{k=1}^c \frac{d_{ij}^{(2/(m-1))}}{d_{ik}}} \quad (9)$$

### 2.4.1 Algorithm

1. Select  $m$  ( $m > 1$ ) where  $m$  is a scalar parameter which controls the fuzziness of the subsequent clusters.
2. Initialize the membership function values  $\mu_{ij}$ ,  $i = 1, 2, \dots, n$ ;  $j = 1, 2, \dots, c$ .
3. Calculate the cluster centers  $s_j$ ,  $j = 1, 2, \dots, c$  according to Eq. (8).
4. Compute the Euclidian distance  $d_{ij}$ ,  $i = 1, 2, \dots, n$ ;  $j = 1, 2, \dots, c$ .
5. Update the membership function  $\mu_{ij}$ ,  $i = 1, 2, \dots, n$ ;  $j = 1, 2, \dots, c$  according to Eq. (9).
6. If not converged, go to step 3.

## 2.4.2 Flowchart

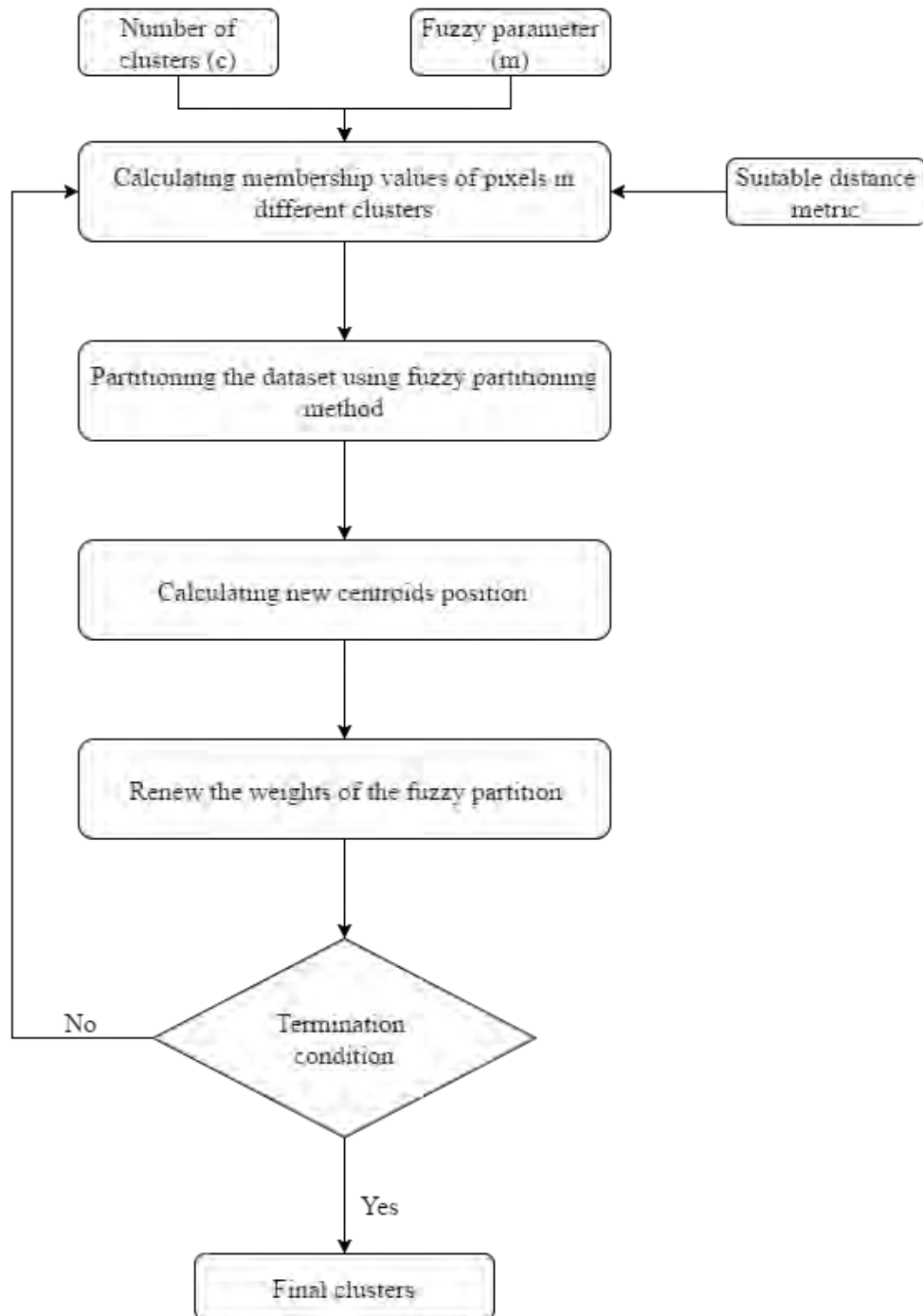


Fig. 2.4.1 Standard FCM flowchart

## 2.5 XieBeni Index

It is a validity measurement technique that is used to identify the average compactness and separation of fuzzy c-partition. It is defined by

$$XB = \frac{\sum_{i=1}^c \sum_{j=1}^n \mu_{ij}^2 \|p_i - s_j\|^2}{n \min_{i,j} \|p_i - p_j\|^2} \quad (10)$$

where  $\mu_{ij}$  is the fuzzy membership value,  $\|p_i - s_j\|^2$  is the square of the Euclidian distance.  $\min_{i,j} \|p_i - p_j\|^2$  is the Separation of fuzzy c-partition, calculated using the minimum distance between cluster centroids. The total number of particles is  $n$  and  $c$  is the total number of clusters [9-11].

# CHAPTER 03

## Literature Review

### 3.1 Previous Works and Technical Overview

Digital Image Watermarking is a solution for copyright protection of multimedia data. But what are the factors that affect its performance? How can it be made better?

The performance of a digital image watermarking scheme is evaluated on the basis of two factors, imperceptibility and robustness. An imperceptible watermarking model does not significantly degrade the quality of the host image after watermarking. Robustness is the ability for a watermarked image to sustain different kind of image processing attacks and not lose the watermark [2, 3].

In recent years, a number of image segmentation techniques have been proposed using Fuzzy C-means (FCM), Particle Swarm Optimization (PSO) and XieBeni Index [10, 12]. Segmenting an image groups it into homogenous regions so that the image can be further processed efficiently.

Kakar et al [12] proposed an image segmentation technique which showed that addition of an optimization algorithm greatly increases the performance of Standard FCM clustering. In order to validate the clustering, a validity measure XieBeni was included with FCM clustering.

In [10], Das et al established an image segmentation method which proved that incorporation of spatial information into membership function for clustering can give us colossal benefit. As a result, priori knowledge of number of partitions is not required for FCM. It also produces clustered regions which are found to be more uniform in the presence of noise.

Aleisa [13] clarified that extraction of Region of Interest (ROI) provides an upper hand when watermarking is done in the non-region of interest. Combination of PSO, ROI and DWT forms an intelligent watermarking scheme for brain magnetic resonance images.

From the information collected above, we deduced that if the host image is broken down into uniformly clustered regions the watermark embedding strength will increase therefore ensuring



efficient watermarking. Additionally, integrating a cluster validity index can ensure optimal image clustering. This gave us the incentive to propose a model where we combined PSO, FCM, XieBeni Index and DWT for watermarking any digital image adaptively.

## **3.2 Methodology**

### **3.2.1 Data collection**

We used the datasets ORL database [14] and SIPI database [15] in order to assess the proposed watermarking scheme. Only images of dimension 512 x 512 were used for both host and watermark images. Before applying our proposed method, the ORL database images underwent grayscale conversion.

### **3.2.2 Tools used**

We used MATLAB R2010a Simulation tools for data analysis.

# CHAPTER 04

## Proposed Model

### 4.1 System Design

- Block 1: A grayscale image is taken as the host image
  - The image is pre-processed by applying PSO algorithm
- Block 2-4: The image is clustered using XFCM
  - The objective function is minimized in the subsequent step
  - XieBeni index is minimized to fulfil the termination criteria of XFCM
- Block 5: A grayscale image is taken as the watermark image
  - The host image undergoes 2-level DWT decomposition
  - The watermark is embedded in the high frequency sub-band
- Block 6: IDWT is applied for the extraction step, it outputs the extracted watermark image and the host image
- The watermarked image is attacked using common image processing techniques
- The watermark is extracted from the attacked image
- The two extracted watermarks are matched to see how much of the quality remains intact

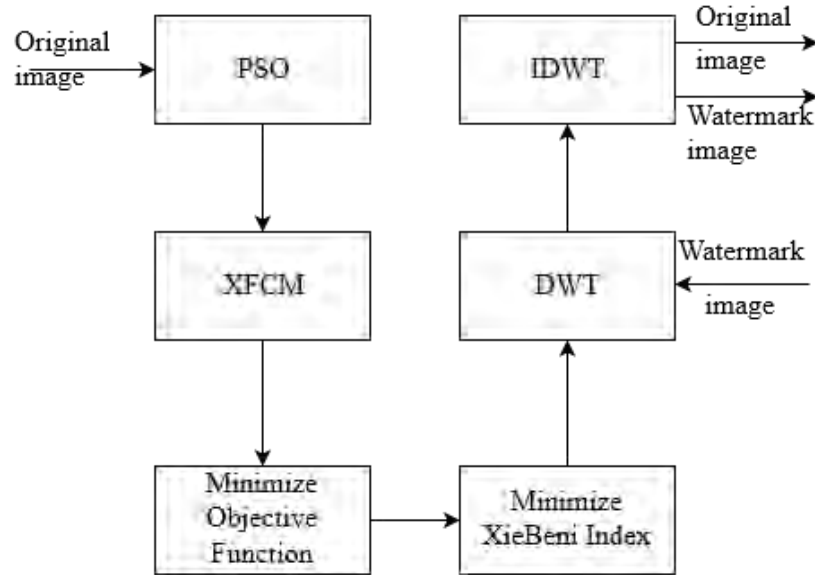


Fig 4.1.1. Block diagram of the proposed model

PSO algorithm is used as a pre-processing step in order to fragment the image into uniform regions. It acts as a helping hand to the clustering method by making it easier for HVS to notice meaningful regions. FCM is sensitive to initialization and can get stuck in the local optima. Therefore, it is essential that the number of clusters selected be optimal. To ensure that, a cluster validity measure can be added to FCM.

In this paper, we proposed a watermarking scheme where XieBeni Index [9] is integrated with FCM (XFCM) and combined with wavelet transform DWT. On minimizing the objective function of FCM, we minimize the XieBeni Index to output an optimally clustered image. XFCM is used for image segmentation before applying digital image watermarking by DWT. PSO algorithm is used as a pre-processing step in order to fragment the image into uniform regions. It acts as a helping hand to the clustering method by making it easier for HVS to notice meaningful regions.

In order to embed watermark, two-level DWT is applied using Algorithm 1. XFCM portion of Algorithm 3. clusters the host image exposing the most suitable areas for watermark embedding. The watermark may be more robust if embedded in the low frequency sub-bands since it contains most of the image energy. However, it might degrade the image quality so we chose the high

frequency sub-bands for embedding watermark. The high frequency bands contain edge and texture-specific information whose changes cannot be observed by HVS [4].

The extraction process administers Inverse Discrete Wavelet Transform (IDWT) function which simply reverses the process of DWT to acquire the watermark bits re-composing the watermark image. The procedure of proposed model is presented in Algorithm 3.

## 4.2 Algorithm

1. Run PSO (Algorithm 2.4.1) for pre-processing.
2. XFCM algorithm:
  - 2.1. Initialize the parameters  $m$ , maximum iteration, membership function  $\mu_{ij}$ , where,  $i = 1, 2, \dots, n; j = 1, 2, \dots, c$ .
  - 2.2. Calculate the cluster centers  $s_j, j = 1, 2, \dots, c$ , using Eq. (8).
  - 2.3. Determine the Euclidian distance  $d_{ij}, i = 1, 2, \dots, n; j = 1, 2, \dots, c$  using Eq. (7).
  - 2.4. Update the membership function  $\mu_{ij}$ , using Eq. (9).
  - 2.5. Compute objective function  $J_m$ , using Eq.(6).
  - 2.6 Compute XieBeni index XB using Eq. (10).
  - 2.7 If XFCM termination condition is not met, go to step 2.2.
3. Apply DWT (Algorithm 2.2.1) for embedding and extracting watermark.

### 4.3 Flowchart

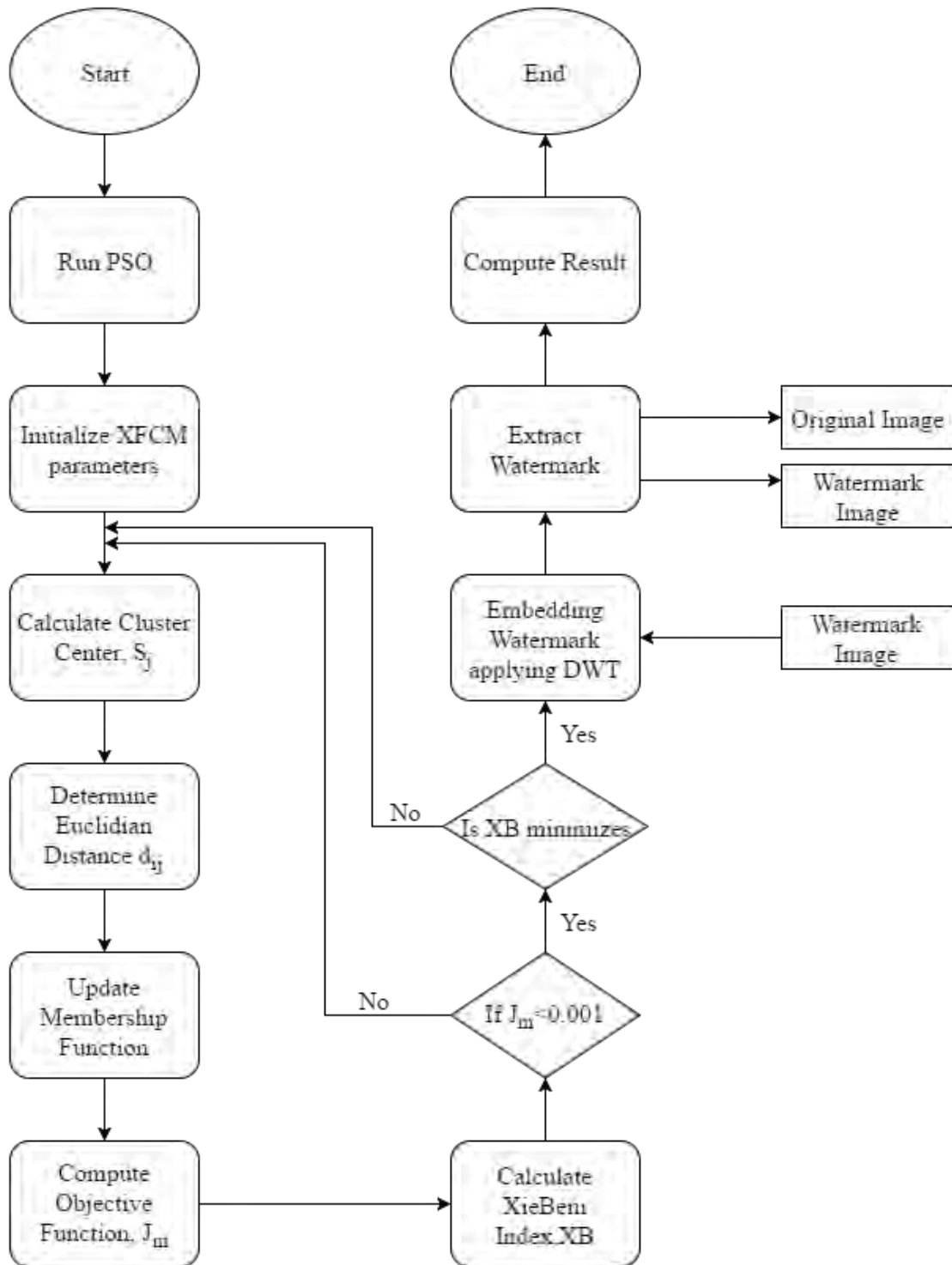


Fig 4.3.1. Flowchart of the proposed model

# CHAPTER 05

## Experimental Results

We used the datasets ORL database [12] and SIPI database [13] in order to assess the proposed watermarking scheme. Only images of dimension 512 x 512 were used for both host and watermark images. Before applying our proposed method, the ORL database images underwent grayscale conversion

In order to tune the host image, PSO algorithm is run applying Algorithm 2.3.1 with the following settings:  $c_1 = c_2 = 2.0$ ,  $P = 10$ ,  $w = 0.9$ ,  $r_1$  and  $r_2 =$  random numbers in range  $[0, 1]$ . The termination criteria is when the algorithm cannot improve  $g_{best}$  in 100 consecutive iterations [5].

XFCM in Algorithm 3 is run with following settings: maximum iteration = 15 and  $m = 2$ . The XFCM termination condition is when the objective function is minimized,  $J_m < 0.001$  and calculated XB is minimum [2].

In order to measure the imperceptibility of the model, we evaluated the MSE and PSNR values of the images using Eq. (11) and Eq. (12).

$$MSE = \frac{\sum_{a=0}^{C-1} \sum_{b=0}^{D-1} [D(a,b) - D'(a,b)]^2}{C \times D} \quad (11)$$

where  $D$  = host image,  $D'$  = watermarked image with size  $C \times D$  [11]

$$PSNR = 10 \log_{10} \left[ \frac{D^2 M}{MSE} \right] \quad (12)$$

where  $D_M$  = maximum value of pixels in image  $D$  [11]

The robustness of the method is evaluated by Correlation Coefficient using Eq. (12).

$$\rho = \left[ \frac{\sum_{a=0}^{C_w-1} \sum_{b=0}^{D_w-1} [Z(a,b) \times Z'(a,b)]}{\sum_{a=0}^{C_w-1} \sum_{b=0}^{D_w-1} Z'(a,b)^2} \right] \quad (13)$$

where  $Z$  and  $Z'$  are embedded and extracted watermark of size  $C_w \times D_w$  [11]

Watermarking was done using three-different models. The extracted images were matched against original watermarks without attacks and performance was evaluated using PSNR, MSE, CC. As presented in Table II, the proposed method gave superior results when compared to other watermarking models.

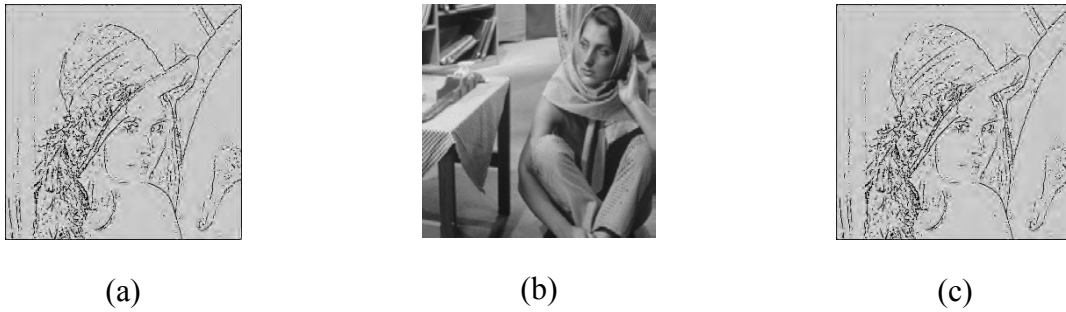


Fig 5.1. (a) Host image (b) Watermark image (c) Watermarked image

Different types of attacks such as jpeg compression, noise addition, histogram equalization, re-watermarking were introduced to the watermarked image. The original watermark image is compared with the extracted watermarked image after undergoing various attacks. The calculated values of the images recorded in Table II-III presents the results of different attacks.

TABLE II: PERFORMANCE ANALYSIS OF PROPOSED MODEL

Error metrics	Watermarked Values		
	<i>FCM-DWT model</i>	<i>PSO-DWT model</i>	<i>Proposed model</i>
<b>PSNR</b>	38.17	37.81	<b>38.25</b>
<b>MSE</b>	39.96	43.44	<b>39.19</b>
<b>CC</b>	0.9933	0.9927	<b>0.9934</b>

TABLE III: MSE VALUES AFTER VARIOUS ATTACKS

Attacks	MSE values		
	<i>FCM-DWT model</i>	<i>PSO-DWT model</i>	<i>Proposed model</i>
<b>JPEG (30%)</b>	41.22	50.21	<b>39.38</b>
<b>JPEG (50%)</b>	41.32	48.16	<b>39.31</b>
<b>JPEG (70%)</b>	41.41	47.27	<b>39.27</b>
<b>Salt &amp; Pepper noise [0.02]</b>	41.22	50.21	<b>39.38</b>
<b>Median filter</b>	<b>582.81</b>	1243.29	1202.00
<b>Scaling (50%)</b>	1255.42	1357.34	<b>1201.98</b>
<b>Speckle [0.04]</b>	41.22	50.21	<b>39.38</b>
<b>Re-watermark</b>	40.08	41.84	<b>39.44</b>
<b>Histogram</b>	<b>2190.38</b>	4647.16	4392.84

In order to verify the quality of the watermark, various kinds of attacks were used. JPEG compression with varied percentage, salt & pepper noise, median filter, speckle noise, image scaling, histogram equalization and re-watermarking was applied. The PSNR (Table III) and MSE (Table VII) values of the extracted watermarks were compared to the original watermark image to determine the imperceptibility of the watermarking scheme. Table III and Table VII shows imperceptibility is sustained by the proposed model in most cases.



TABLE IV: CORRELATION COEFFICIENT VALUES AFTER JPEG COMPESSION










	<i>FCM-DWT</i>	<i>PSO-DWT</i>	<i>Proposed model</i>
<b>JPEG (30%)</b>			
<b>JPEG (50%)</b>			
<b>JPEG (70%)</b>			
<b>CC</b>	0.9931	0.9916	<b>0.9934</b>

TABLE V: CORRELATION COEFFICIENT VALUES AFTER RE-WATERMARKING




	<i>FCM-DWT</i>	<i>PSO-DWT</i>	<i>Proposed Model</i>
<b>Re-watermark</b>			
<b>CC</b>	0.9933	0.9930	<b>0.9934</b>

TABLE VI: : CORRELATION COEFFICIENT VALUES AFTER NOISE ADDITION




	<i>FCM-DWT</i>	<i>PSO-DWT</i>	<i>Proposed model</i>
<b>Salt &amp; Pepper (0.002)</b>			
<b>CC</b>	0.9781	0.9785	<b>0.9816</b>

TABLE VII: PSNR VALUES AFTER VARIOUS ATTACKS

<b>Attacks</b>	<b>PSNR values</b>		
	<i>FCM-DWT model</i>	<i>PSO-DWT model</i>	<i>Proposed model</i>
<b>JPEG (30%)</b>	38.03	37.18	<b>38.23</b>
<b>JPEG (50%)</b>	38.02	37.38	<b>38.24</b>
<b>JPEG (70%)</b>	38.00	37.49	<b>38.27</b>
<b>Salt &amp; Pepper noise [0.02]</b>	38.03	37.18	<b>38.23</b>
<b>Median filter</b>	<b>26.53</b>	23.24	23.39
<b>Scaling (50%)</b>	23.20	22.86	<b>23.53</b>
<b>Speckle [0.04]</b>	38.03	37.18	<b>38.23</b>
<b>Re-watermark</b>	38.16	37.97	<b>38.28</b>
<b>Histogram</b>	<b>20.78</b>	17.51	17.76

# CHAPTER 06

## Conclusion and Future Work

### 6.1 Conclusion

In this paper, we have proposed a watermarking scheme based on XieBeni integrated Fuzzy C-means in the wavelet domain. It can be used for digital image copyright protection. Unlike most of the existing watermarking schemes, we used same size images for both host and watermark image therefore it can also be used for side information conveyance with ease. Initially the host image is pre-processed using PSO which aids in the clustering process. Fuzzy C-means is sensitive to initial values and tend to get stuck in local minima. To overcome the shortcoming, we added XieBeni so optimal number of clusters can be obtained before we watermarked the clustered image using DWT. The contribution of the paper is that we proposed a watermarking scheme which provides good imperceptibility and robustness against common image processing attacks. The quality degradation of the host image is minimal in most cases and the watermark is invisible to HVS.

### 6.2 Future Work

In this paper, we only worked with grayscale images. The RGB images need to be broken down into their Red, Green, Blue components and processed separately. We hope to work with colored images in future.

We look forward to implementing a fully-functional watermarking system with a friendly User Interface (UI) so that our project can be directly used by day-to-day functional activities e.g. broadcasting sector, photography and so on. We believe it will open doors to more opportunities in the fields depending vastly on multimedia data transfer and will help keep up with the constantly digitalizing world.

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