Medical Image Authentication through Watermarking Preserving ROI

Dissertation

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by

Sonika C. Rathi
Roll No: 121022005

under the guidance of

Prof. V. S. Inamdar

Department of Computer Engineering and Information Technology
College of Engineering, Pune
Pune - 411005.

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Dedicated to

my mother

Smt. Kavita C. Rathi

and

my father

Shri. Chandrakant D. Rathi

DEPARTMENT OF COMPUTER ENGINEERING AND INFORMATION TECHNOLOGY,
COLLEGE OF ENGINEERING, PUNE

CERTIFICATE

This is to certify that the dissertation titled

Medical Image Authentication through Watermarking Preserving ROI

has been successfully completed

By

Sonika C. Rathi
(121022005)

and is approved for the degree of

Master of Technology, Computer Engineering.

Prof. V. S. Inamdar,
Guide,
Department of Computer Engineering
and Information Technology,
College of Engineering, Pune,
Shivaji Nagar, Pune-411005.

Dr. Jibi Abraham,
Head,
Department of Computer Engineering
and Information Technology,
College of Engineering, Pune,
Shivaji Nagar, Pune-411005.

Date : ________________

Abstract

Telemedicine is a well-known application, where enormous amount of medical data need to be securely transferred over the public network and manipulate effectively. Medical image watermarking is an appropriate method used for enhancing security and authentication of medical data, which is crucial and used for further diagnosis and reference. This project focuses on the study of medical image watermarking methods for protecting and authenticating medical data. Additionally, it covers algorithm for application of water marking technique on Region of Non Interest (RONI) of the medical image preserving Region of Interest (ROI).

The medical images can be transferred securely by embedding watermarks in RONI allowing verification of the legitimate changes at the receiving end without affecting ROI. Segmentation plays an important role in medical image processing for separating the ROI from medical image. The proposed system separate the ROI from medical image by GUI based approach, which works for all types of medical images. The experimental results show the satisfactory performance of the system to authenticate the medical images preserving ROI.

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I take this opportunity to express my hearty thanks to all those who helped me in the completion of my project work. I am very grateful to the authors of various articles on the Internet, for helping me become aware of the research currently ongoing in this field.

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Sonika C. Rathi
College of Engineering, Pune
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Chapter 1

Introduction: Digital Watermarking

1.1 Digital watermarking

In recent year all the business applications are moving towards the digital era, because of great development in latest technologies such as in the area of communication, networked multimedia system, digital data storage etc. Also from the last two decades use of internet is rapidly increased in business environment towards achievement of effectiveness, convenience and Security by introducing the digitization in their work.

It was estimated that in 1993 the Internet will carry only 1% of the information however by 2000 this figure had grown to 51%, and by 2007 more than 97 % information was carried away across the globe. A study conducted by JupiterResearch says that 1.1 billion people have regular Web access and use application like electronic mail, instant messaging, social networking, online messaging etc. which, helps in growth & knowledge sharing in different domains such as education, research, development, Medical, and many business etc. In business applications to speed up the business process communication use of digital media has been drastically increased. This digital data includes text, images, audio, video and software which are transferred over open public network, hence there is need to protect this data. There are many techniques that are available for protection of this digital data, such as encryption (cryptography), authentication and time stamping. Also there is another method that improved the protection of digital data by merging a low level signal directly into the digital data. This low level signal is known as watermark, that uniquely identifies the ownership and provide the security to the digital data and can be easily extracted.

The process of embedding the watermark into a digital data is known as Digital Watermarking. It is a process of embedding unremarkable logos or labels or information data or pattern into the digital data [1]. The concept of digital watermarking is associated with the stegnography. It is defined as covered writing, which hides the important message in a covered media while, digital watermarking is a way of hiding a secret or personal message to provide copyrights and the data integrity. Digital image watermarking is a new approach, which is suitable for medical, military, and archival based applications. The embedded watermarks are difficult to remove and typically imperceptible, could be in the form of text, image, audio, or video.

The embedding of secret watermark in digital data, no matter how much invisible it may be. However it leads to some degradation in the resultant embedded digital data. To overcome this and to retrieve the original data, reversible watermarking has been implemented, which considered as a best approach over the cryptography. In cryptography after encryption the resultant data may not be visible or understandable also at the time of retrieval this may lead to loss of semantic information of host data, which is not in case of watermarking. In digital data several watermarks can be embedded at the same time and this is known as multiple watermarking technique. A digital watermark also considered as digital signature which provides the authenticity. A given watermark may be unique to each copy (e.g. to identify the intended recipient), or be common to multiple copies (e.g. to identify the document source).

1.2 Principle of Digital Watermarking

Basically, digital watermarking is consisted of two main processes, namely embedding process and extracting process. During the embedding process, watermark is embedded into the multimedia data (digital data). The original digital data (multimedia content) will slightly modified after embedding the watermark, this modified data is called as watermarked data. While in extraction process this embedded watermark is extracted from the watermarked data and recovers the original multimedia data. The extracted watermark is then compared with the original watermark; if the watermark is same it results in authenticated data. During the transmission of the watermarked data over the public network attacker may tamper the data, and if any modification in the data can be detected by comparing the extracted watermark with the original watermark.

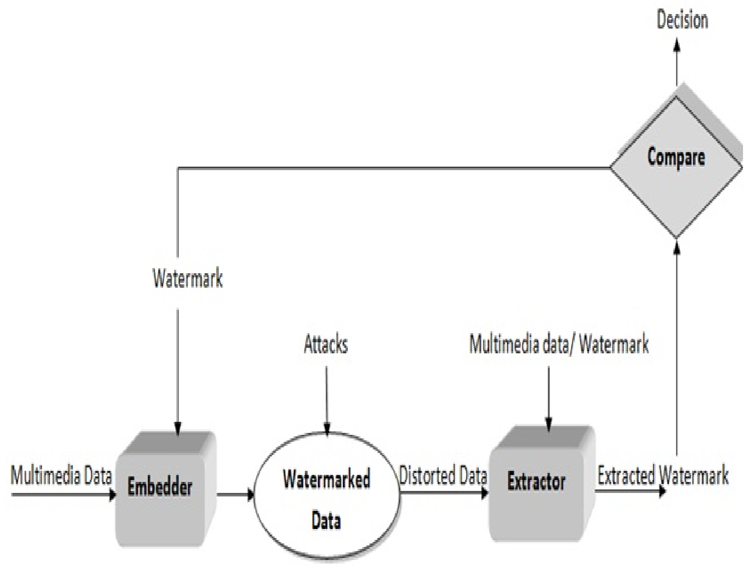

Figure 1.1: A Typical Watermarking System

A typical watermarking system is shown in Figure 1.1 which includes watermark embedder and watermark extractor. The inputs to the embedder are multimedia data and watermark, which is to be embedded into the original multimedia data. The output of watermark embedder is watermarked data (watermarked content). The inputs to the watermark extractor depending on the method are original multimedia or original watermark. The watermark extraction process involves two steps [2]. In the first step one or more pre-process is applied on the watermarked data to extract a vector called extracted watermark. Then the second step is to determine whether the extracted watermark is same as original watermark by comparing the extracted watermark with the original watermark called reference watermark. The result of second step is to measure the confidence by indicating how likely the original watermark is present in the digital data [3]. The multimedia data in Figure 1.1 includes text [4], image [5], audio file [6], video [7], 3D data [8, 9], and object [10].

Suppose that X is the original multimedia data and W is the watermark to be embed. In digital watermarking system a embedding function E(.) takes X and W as a input values and gives X' i.e. watermarked data as a output. X' is obtained as:

$$X' = p\,(X, W) \tag{1.1}$$

The embedding algorithm is considered as robust if watermark is embedded in a way such that it can survive even if the watermarked data X' goes through several attacks. During extraction process the extraction function D(.) is defined as:

$$W' = D\,(X', [X], [W]) \tag{1.2}$$

Where W' is retrieved watermark, X and W enclosed in braces [ ]can be optional inputs for extraction function, which depends on the application. For example [X] is used when the watermarking system is non-blind, this system is suitable for the application where to extract the watermark original image is needed. If the watermarking system is blind the input to the extraction function is [W] only.
A typical watermarking should satisfy the following requirements.

- The watermark W should be extracted from X' with or without X
- X' should be as close to X as possible
- If X' is not manipulated/modified, the extracted watermark should be same as W
- For robust watermarking, if X' is modified, W' should still match W to give clear judgment of the existence of watermark
- For fragile watermarking, after even the slight manipulation to X' extracted W' should be totally different from W. In such system W indicates the tampering to the X'

1.3 Types of Watermarking System

Depending on the application, watermarking system can be of different types.

1.3.1 Visible watermarking system

In visible watermarking system watermark (text or image) is semi-transparently embedded into original data. Visible watermarking is more robust against image transformation attacks, which provides copyrights protection of intellectual property thats in digital format. In visible watermarking watermarked data is view as digitally stamped document.

1.3.2 Invisible watermarking system

In invisible watermarking system watermark is embedded into the original data in such a way that the embedded watermark should not be visible by naked eyes. Only electronic devices (or specialized software) can extract the embedded information to prove the authenticity. Such type of system is used to identifying the source, author, creator, owner, and distributor or authorized consumer of a multimedia data.

1.3.3 Blind watermarking system

A watermarking technique is said to be blind, if to extract the watermark from watermarked data it does not need original image. The blind watermarking system is also known as oblivious. Blind watermarking system is more popular because it decreases the overhead of cost and memory for storing original data.

1.3.4 Non-blind watermarking system

The watermarking techniques in which to extract the watermark, it requires the original data is known as non-blind watermarking system. It is more robust than blind watermarking system.

1.3.5 Robust watermarking system

A watermarking system is said to be robust, if any modification on the watermarked data results in no change into watermark value. That is extracted watermark information from the tampered watermarked data would be same as original watermark information. A robust watermarking system resist against wide range of intentional and unintentional attacks such as, image enhancement, filtering, noise addition, JPEG compression and geometrical transformations, collusion and forgery attacks.

Robust watermarking systems have been proposed to be implemented in number of application. Such as copyright protection, finger printing and access control.

Copyright protection is one of the main applications of robust watermarking system. In copyright protection application the idea is to embed information about the copyright owner into the multimedia data to prevent parties from claiming to be the rightful owners of the data. The robust watermark embedded into the content is detectable despite common image processing manipulations. finger printing is used to trace authorized users who violate the license agreement and distribute the copyrighted material illegally. Thus, the information embedded in the content is usually about the customer such as customer's identification number.

1.3.6 Fragile watermarking system

In fragile watermarking system embedded watermark in host data can be easily destroyed. This property is useful to identify whether a multimedia data is modified/ manipulated or not? By embedding then fragile watermark into multimedia data, the authenticity of multimedia data can be achieved. Any small manipulation on the watermarked data will lead to distortion in corresponding embedded fragile watermark. At the end side by comparing the extracted watermark with original watermark, it can be easily identified whether the multimedia data is manipulated or not. The different applications where fragile watermarking can be used are document authentication, evidence authentication, complete authentication etc.

1.4 Properties of Digital Watermarking

An effective digital watermarking algorithm must have number of properties. This section describes the number properties of digital watermarking algorithm.

1.4.1 Imperceptibility

The basic requirement of digital watermarking is to have the watermarked image should look alike as the original image. This confirms there is not much degradation on the original image. This property is known as imperceptibility or transparency of the watermarking system [11]. The embedded watermark should not be visible to human eye. To calculate the imperceptibility, generally Peak Signal to Noise Ratio (PSNR) is used [11].

1.4.2 Robustness

The capability of survival of watermark against both legitimate and illegitimate attacks is referred as robustness. All watermarking system needs to resists against any legitimate and illegitimate attacks, except fragile watermarking system. For manipulation recognition in original data the watermark has to be fragile to detect altered media. Robustness depends on watermarks information capacity, visibility and strength. Generally a good watermarking algorithm should be robust against filter processing, noise addition, geometrical transformations such as rotation, scaling, translation and lossy compression such as JPEG compression [12].

1.4.3 Security

The watermarking system should be secured i.e. hacker should not be in position to extract the watermark without having the knowledge of embedding algorithm. Watermarking system must be capable of stand firm against different attacks [2]. Attacks try to remove, modify or embed (unwanted information) into the watermark. Attacks are mainly classified in two different types i.e. passive attack and active attack. Passive attack only detects the watermark information, while active attack tries to modify the watermark information.

1.4.4 Complexity

The time and effort needed to embed and retrieve the watermark information is known as complexity of the watermarking system. The complex algorithm in watermarking system requires more software and hardware resources to implement it, which results in increasing the computation cost. To reduce the computational cost of watermarking system, it should be less complex. Such as in telemedicine domain, to cut the cost of bandwidth consumption during the transmission of medical data less complex watermarking algorithms are implemented.

1.4.5 Capacity

Capacity of the watermarking system describes embedding of maximum amount of watermark information i.e. embedding the multiple watermarks in single data. The higher capacity of embedding information in a data can be obtained by compromising either imperceptibility or robustness of algorithm [13].

1.4.6 Invertibility

This property of digital watermarking system describes the possibility of generating original data during the extraction process of watermark.

1.4.7 Verification

This property defines the procedure of verification i.e. private key verification and public key verification, depending on its respective algorithm.

1.5 Watermarking Techniques

There are different kinds of watermarking techniques are in place, which are differentiated on the basis of types of document, types of domain, etc [14]. The various types of watermarking according to different categories are shown in Figure 1.2. Watermarking techniques are broadly divided into four types:

1. According to working domain
2. According to types of document
3. According to human perception
4. According to application

These four categories are further classified as below

1. According to types of document
    - Text watermarking
    - Image watermarking
    - Audio watermarking
    - Video watermarking
2. According to human perception
    - Visible watermarking
    - Invisible watermarking

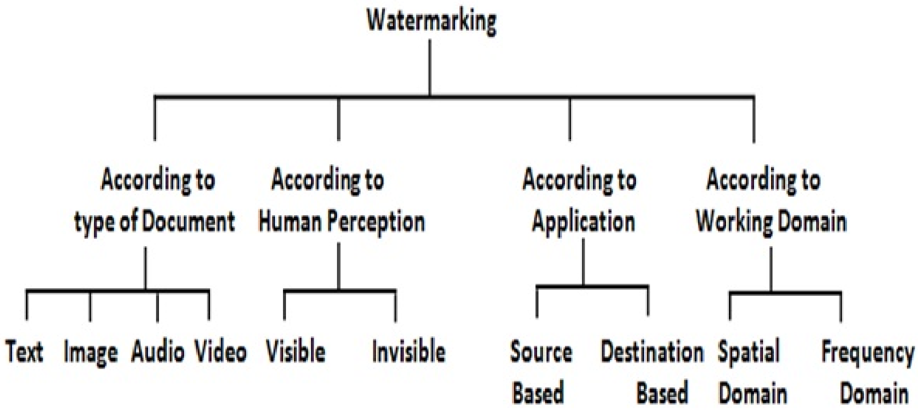

Figure 1.2: Types of Watermarking Techniques

3. According to Application
   Source based watermarking: This approach is used for the ownership authentication where unique watermark is embedded into all copies of data.
   Destination based watermarking: This approach is used in the application where the tracing of buyer is done for the purpose of illegal reselling. Here for each distributed copy a unique watermark is used.

4. According to working domain

   - Spatial domain
   - Frequency domain

Watermark can be applied in spatial domain or it can be applied in frequency domain.

1.5.1 Spatial domain watermarking

Spatial domain watermarking method hides the watermark directly within the host data [15, 16]. This approach is easy and simple to implement. The advantage of this approach is the spatial localization of the embedded data can be achieved automatically even after the watermarked content goes under some attacks. Another advantage of spatial domain watermarking is that, it allows the control on maximum difference between the original image and watermarked image due to which design of near-lossless system can be possible [13]. Spatial domain watermarking is applied in number application. There are various ways of applying spatial domain watermarking.

(a) Additive Watermarking

Additive watermarking is most straightforward method for embedding the watermark in spatial domain. It adds pseudo random noise pattern to the pixel of host data. To ensure that embedded watermark should be detected, the noise to add in host data is generated by a key. The same key is used at the time of extraction process.

(b) Least Significant Bit Modification

This method is very common for embedding the watermark in the host data. It relies on the way of manipulating the LSBs of host data, in a manner which is not detectable by human eye. The basic idea for this method is to replace LSBs of host data by same size of binary watermark.

1.5.2 Frequency domain watermarking

However, the spatial-domain watermark insertion is simple and easy to implement, but it is fragile versus various attacks and noise. To get the better robustness as well as imperceptibility, watermarking is done in frequency domain. Frequency domain is also known as multiplicative watermarking. There are several watermarking techniques in different frequency domain such as Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Discrete Curvelet Transform, and Discrete Counterlet Transformation [17]. This section covers the details of DWT domain.

Discrete Wavelet Transform (DWT)

All transform domain watermarking algorithms generally follows three steps i.e. (i) Data transform (ii) watermark embedding and (iii) Watermark recovery. Transformation of host data can be applied either on whole data [18], or in block by block manner [19]. Wavelets are mathematical function that cuts the data into different frequency components, and according to the resolution matched to its scale wavelet function study each component. The advantage of wavelet transform over traditional Fourier methods is that it analyses the signal which contains discontinuities and sharp spikes. Other advantage of wavelet transform is, it captures both frequency and location information (location in time). The basic idea for 1D DWT is it decomposes the signal (host data) into high frequency part and low frequency part. The edge components of the signal are largely contained to the high frequency part. The low frequency part is again split into two parts low and high frequency part. This process can be continued till an arbitrary number, which is usually determined by the application at hand. Furthermore, the original signal can be reconstructed by inverse DWT (IDWT) process. In case of 2D-DWT we get four subbands from one level, that are Low-Low level (LL), High-High Level (HH, Low-High level (LH) and High-Low level (HL). The LL subband contains the low level details of the image. In the next level, the 2D-DWT of the LL subband is obtained and this is repeated in each succeeding level.The filter bank structure used in wavelet decomposition of an image is shown in Figure 1.3. Where h[n] is high pass filter, g[n] is low pass filter and W is wavelet function.

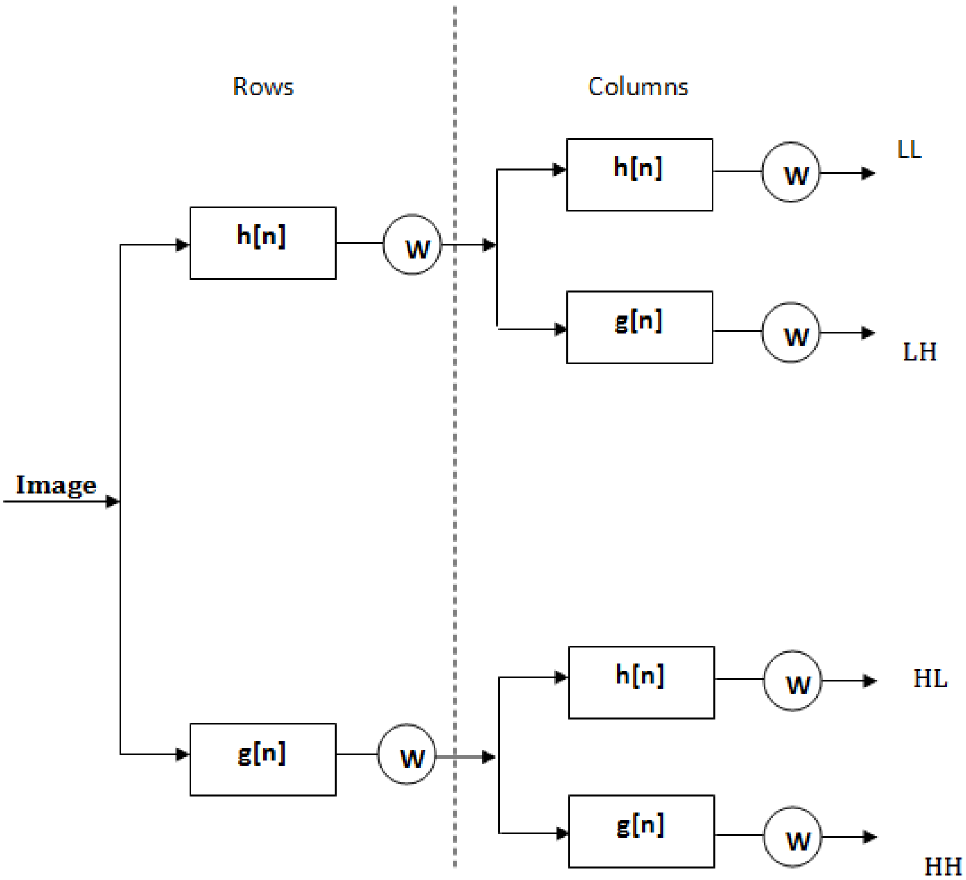

Figure 1.3: The filter bank structure used in wavelet decomposition of an image

H[n] and G[n]are defined as below:

$$H[n] = \sum_{k} h_k e^{-jkn} \tag{1.3}$$

$$G[n] = \sum_k g_k e^{-jkn} \quad (1.4)$$

There are number of basic function that can be used to perform wavelet transform on given signal. Such as, lazy, haar, daubechies wavelets (db1, db2, db3, etc.), meyer, etc.

1.6 Application of Watermarking

Increasing research on watermarking from the past decades has been largely motivated by its applications in copyright management and protection. The digital watermarking technique is highly suitable for medical, military, and archival based applications.

- Broadcast monitoring is the well known application of watermarking, which helps advertising agencies to track the specific video broadcast by a TV Channel or station. Embedding the watermarked video to the host video will provide you easier way to track and monitor the broadcast.
- Owner Identification is also a well known application of watermarking, which helps in identifying the owner of video or image. Such as copyright authorities, where instead of providing copyright notice with every image or video the watermark could be directly embedded in to the image or video itself.
- Another well know application of watermarking is copy control which helps preventing the illegal copy of songs or images of movies etc. Where by embedding watermark in songs or images of movie would instruct a watermarking compatible DVD or CD writer to not write the song or movie as it is an illegal copy.
- With the help of watermarking Transaction Tracking can be achieved by recording the transaction details in the history of a copy in digital work. For example issuing each recipient a legal copy of movie by embedding the watermark (different watermark for different recipient) will help in tracking the source of leak in case of movie leaked to the internet.
- Medical image watermarking is one of the important applications of watermarking. Medical image authentication systems which can not only authenticate medical images but would also be able to secretly communicate auxiliary information can be achieved by watermarking technique. Only the

authorized people of the hospital would thus be able to modify the content of medical image.

1.7 Thesis Outline

The outline of report is described below:
Chapter 2 provides brief introduction to the medical image watermarking, where it explains the requirements of medical image watermarking. The study of different segmentation algorithm in place, to separate the ROI from medical image and the available algorithm for medical image watermarking are discussed in chapter 3.

Chapter 4 discuss about the proposed system for medical image watermarking preserving ROI. The proposed system has been applied successfully against all existing medical imaging. Chapter 5 shows the experimental results achieved by using the proposed system. Chapter 6 provides insight on conclusion and the future work.

Chapter 2

Medical Image Watermarking Introduction

Speedy development of internet in every field leads to availability of digital data to the public. Internet has been spread in many applications like telemedicine, online-banking, teleshopping etc. One of this application telemedicine is crucial one, where Internet is used to transfer or receive medical data by healthcare professional. Due to advancement in information and communication technologies, a new context of easier access, manipulation, and distribution of this digital data have been established [20]. The medical images can be readily shared via computer networks and easily used, processed, and transmitted by using great spread network [21, 22].

In the last decades, uses of advanced electronic and digital equipments in health care services are increased, where traditional diagnosis system has been replaced by e-diagnosis system. In fact, in most of the hospitals physicians diagnose their patients by relying on the provided electronic and digital data (such as Ultrasonic, Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and X-ray images). This results in generation of large number of electro digital data (i.e. medical images) continuously at various health care centers and hospitals around the world. The typical e-diagnosis model is shown in Figure 2.1, where medical image can be sent by patient through the internet to physician. One physician can transfer the medical image to anther physician for second opinion. The medical images are stored in patient historical database for future diagnosis.

In number of medical applications, special safety and confidentiality is required for medical images, because critical judgment is done on medical images, which leads to the proper treatment. Therefore, it must not be changed in an illegitimate way; otherwise, an undesirable outcome may results due to loss of decisive information. Therefore, there is a need to provide a strict security in medical images to ensure only occurrence of legitimate changes. Now-a-days exchange of medical images between hospitals located in different geographical location is very common. Moreover, as this exchange of medical reference data done via unsecured open networks leads to the condition of changes to occur in medical images and creates a threat which results in undesirable outcome. Considering this fact, demand of security is getting higher due to easy reproduction of digitally created medical images. For copyright protection and authentication of these medical images, dig-

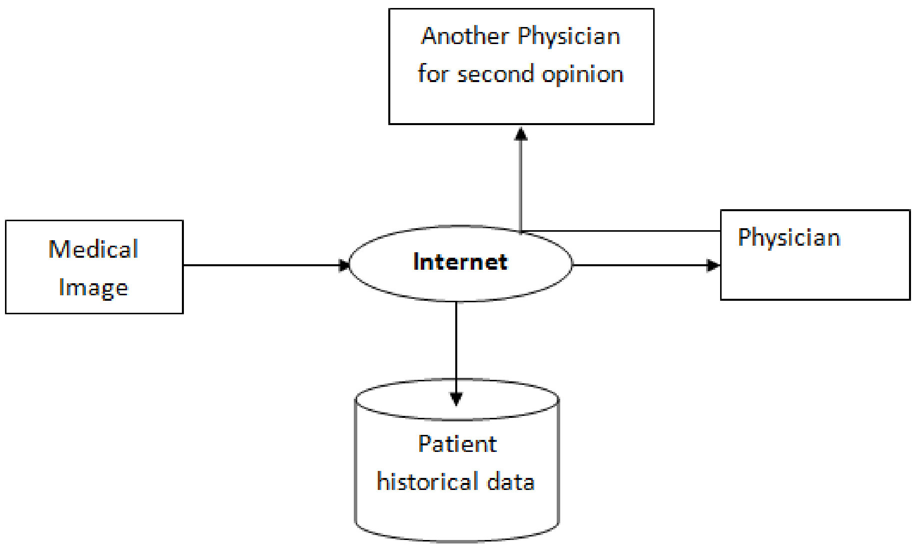

Figure 2.1: A typical e-diagnosis Model

ital watermarking is an emerging technique, which includes the embedding and extraction process. Embedding process hides some secrete information in to medical images. This secret information is extracted during the extraction process. If failure occurs in extraction process the physician would come to know that there has been some kind of tampering with that image, and he would take precaution of not making diagnosis based on that image. However, if the extraction process extracts the correct watermark, which generally consumes a few seconds, physician can continue with diagnosis.

2.1 Principle of Medical Image Watermarking

The typical block diagram for medical image watermarking is given in Figure 2.2. Encoder E embeds the watermark W in medical image to provide security and authentication. Decoder D extracts the watermark from watermarked image. By comparing the extracted watermark with original watermark, one can affirm the tampering of medical image.

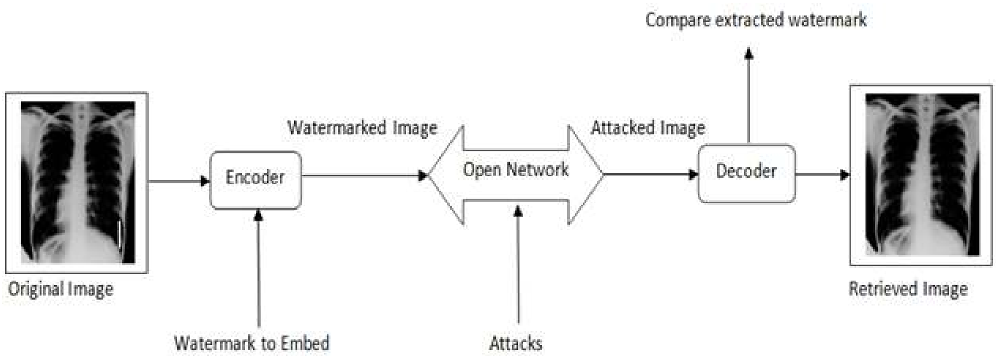

Figure 2.2: Block diagram of Medical Image watermarking

To ensure the reliability and quality of the watermarked image, the performance of watermarking is calculated, which measured in terms of perceptibility. There are two method of calculating the performance measure.

- Mean Square Error (MSE):
  It is simplest function to measure the perceptual distance between watermarked and original image. MSE can be defined as:

$$MSE = \frac{1}{n}\sum_{i}^{n}(I' - I)^2 \tag{2.1}$$

  Where, I is original image and I is watermarked image.

- Peak Signal to Noise Ratio (PSNR):
  It is used to measure the similarity between images before and after watermarking.

$$PSNR = 10\log_{10}\frac{maxI^2}{MSE} \tag{2.2}$$

  Where, max I is the peak value of original image.

2.2 Requirements of Medical Image Watermarking

2.2.1 Imperceptibility

Imperceptibility is one of the strict requirements of the medical image watermarking. Imperceptibility means the embedded watermark should not be visible by human eye. It is often not allowed to alter the medical image contents even after embedding the watermark in some application [23, 20]. The imperceptibility in medical image watermarking can be achieved by two methods. In first method imperceptibility is fulfilled by selecting the Region of Non Interest watermarking [24], in which the watermark is embedded in RONI area of medical image. In this method the Region of Interest (ROI) area of medical image will be distortion free. Imperceptibility can be achieved by reversible watermarking method which recovers the original medical image by undoing the watermark embedding process at the receiving side [25].

2.2.2 Capacity

In medical image watermarking, all the information that are required by the physician such as identification of patient, doctor identification, treatment, etc are embedded in medical image. Therefore, capacity for embedding the payload must be high.

2.2.3 Authenticity

The entitled users (patient, doctor) should have the access to the medical data. This can be achieved by embedding the doctors identification and patient identification in medical images.

2.2.4 Reversibility

At the receiving side the reverse of embedding process should be possible to get the original medical image and embedded watermark. This property is known as reversibility of medical image watermarking.

2.2.5 Complexity

According to the e-diagnosis the medical images are transferred from some remote location to the other side through internet. In such cases speed becomes an important matter, thus the algorithm should be less complex to reduce the execution time.

2.2.6 Intactness of ROI

Medical images hold decisive property and are very crucial and important part of medical information. Such part of the medical image is called as Region of Interest (ROI). The ROI is helpful in providing further diagnosis by the physician. A small bit of distortion in ROI may lead to undesirable treatment for patient. For securing medical images through watermarking ROI should be preserved and the watermarks can be applied on the remaining part of the image called as Region of Non Interest (RONI). Therefore, application of watermarking in medical images can be considered as two-step process which includes:

1. Extracting ROI form the medical images

2. Applying watermarking on RONI

Chapter 3

Literature Survey

Different algorithms are available for segmentation of ROI on the different types of medical images. Additionally, there are different algorithms available for applying watermarking.

3.1 Region of Interest (ROI) Segmentation

Segmentation plays an important role in medical image processing [26, 27]. In medical image analysis segmentation is the first step to be followed, to avoid distortion of ROI [26, 28]. Image segmentation deals with the process of partitioning an image into different regions by grouping together neighborhood pixels based on some predefined similarity criterion [29]. This similarity criterion can be defined by specific properties of pixels in the image. Segmentation in medical imaging is used for the extracting the features, image display and for the measurement of image. The goal of segmentation is to divide entire medical image in to sub regions i.e. (white and gray matter). In addition, this helps in classifying image pixels in to anatomical regions (such as bones, muscles and blood vessels). Defining the borders of ROI in medical image can simplify the procedure of segmentation. In addition, the step of defining borders of ROI is a crucial one, which helps in determining the result of the application as entire analysis fully relies on the output from segmentation step. There are different approaches (for segmenting the image) defined for the different imaging technologies such as CT, MRI, US, colonoscopy etc. Segmentation is semi-automatic procedure and we need to define a seed point in an image. Therefore, the algorithm, which gives perfect result for one application, might not even work for another. Figure 3.1 shows the ROI part of medical image, where physician performs the diagnosis.

We have various existing medical imaging like Computed Tomography (CT),

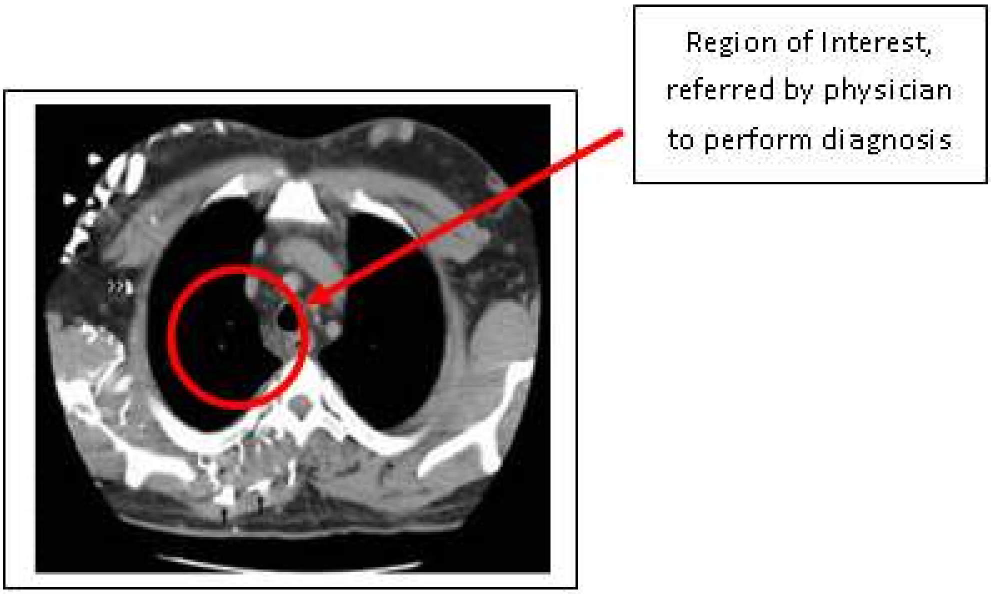

Figure 3.1: Medical image indicating ROI

Magnetic Resonance Imaging (MRI), Ultrasound (US), and Positron Emission Tomography (PET) etc. Here, two most common imaging i.e. MRI and CT scan are discussed in detail with their proposed algorithms.

3.1.1 Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI) provides a wealth of information, which is useful for medical examination. In many applications where MRI is used, segmentation of image into different intensity classes are needed, which is regarded as the best available representation for biological tissues [30, 31]. Segmentation plays very important role in MRI process for deciding the spatial location, selecting the operation path, shape, and size of the focus etc. In segmenting MRI images, main requirement is to care about three problems: noise, partial volume effects (where more than one tissue is inside a pixel volume), and intensity in-homogeneity [32]. Due to irregularities of the scanner magnetic fields-static (BO), radio frequency (B1), and gradient fields, intensity in-homogeneities are caused. These irregularities results in producing spatial changes in static tissues of MRI data. When multiple tissues contribute to a single voxel, by making the distinction between tissues along boundaries more difficult leads to the problem of partial volume effects. Adding noise in MRI images can encourage disconnection between segmentation regions. Therefore, for doing segmentation of MRI data on these three difficulties need to focus. There are four different approaches for doing image segmentation:

thresholding, clustering, edge detection, and region extraction. This section covers various available MRI segmentation algorithms based on following approaches:

- Thresholding approach
- Clustering approach
- Edge detection approach

1. **Thresholding:** Thresholding is one of the easiest and most frequently used techniques to segment MRI data by separating the foreground from background of image [33, 34]. Thresholding approach can further be classified as global thresholding and local (adaptive) thresholding. In global thresholding method, image segmentation is done by providing single threshold value in the whole image whereas, in local thresholding, threshold value is assigned to each pixel of image by using local information around the pixel, and then to determine whether the particular pixel belongs to foreground or background these threshold values are used. Due to simplicity and easy implementation of global thresholding, this method is more popular. P-tile method is one of the earliest thresholding methods based on the gray level histogram [33, 35]. Here P refers to the word percentile. This algorithm stands on the statement Objects in the image are brighter than the background, which occupy a fixed percentage of the picture area. In this algorithm, threshold is defined as the gray level that mostly corresponds to mapping at least P% of the gray level into the object. The experimental results of this method specify that it is suitable for all size of objects, and it provides good anti-noise capabilities. However, this method is not applicable in application where object area ratio is unknown or varies from image to image.

2. **Clustering:** The goal of clustering approach is to group similar objects and separates the dissimilar objects. That is depending on some perceived similarities this grouping of pixels is done. These clusters then lead in providing natural partitions of pixels that corresponds to the different regions in an image. Conventional clustering algorithms require a prior knowledge regarding the number of clusters, clustering criteria, and nature of data, etc. There are many algorithms defined for the clustering, such as K-means clustering, Fuzzy c-means (FCM) clustering, possibilistic c-means, possibilistic-fuzzy clustering, intuitive fuzzy c-means (IFCM), and so on. The objective of clustering, for a given set of unlabeled N samples or data i.e. X= $x_1, x_2, ..., x_n$

is to assign a class label among C labels to each of N samples. This number of labels C, considered as the number of regions or number of groups. One of the most widely used clustering algorithms is Fuzzy c- means (FCM) [36, 37]. In the FCM algorithm, it assigns labels to the data, which are inversely related to relative distance of to the point prototypes that are cluster centers in FCM model. In FCM, proximity of each data or samples, x_k, to the center of cluster, v_i, is defined as membership or label (u_{ki}) of data x_k to the i^{th} cluster of X with following conditions:

$$0 \leq u_{ki} \leq 1 and \sum_{i=1}^{c} u_{ki} = 1, \forall k \tag{3.1}$$

$$U = [u_{ki}]_{NxC} andV = v_1, v_2, ...v_i \tag{3.2}$$

FCM algorithm is acknowledged as one of the best clustering algorithm as it resolves various problems, [36, 38], although it still suffers from undesirable solutions with outliers data [36, 39]. As in FCM algorithm, it requires to provide the exact number of clusters in advance as a prior knowledge. The exact estimation of number of clusters in MRI images, (used in particular for diseased cases), may not be possible to have in advance. To overcome this problem, Krishnapuram and Keller proposed a clustering model named possibilistic c-means (PCM) [36, 38]. In the PCM model the condition of FCM model,

$$\sum_{i=1}^{C} u_{ki} = 1 \qquad \forall k, is\ relaxed\ by\ introducing\ the\ new\ condition\ as \tag{3.3}$$

$$\sum_{i=1}^{C} u_{ki} = C \qquad \forall k \tag{3.4}$$

By providing new condition, PCM model improves its performance over the FCM algorithm, as PCM overcomes the drawback of FCM. PCM is ISODATA based algorithm, which makes use of user defined criteria for merging and splitting clusters to discover the number of natural clusters in the data. However, it is very difficult to define these splitting and merging criteria that can be applied on various MR data based on prior assumptions of intensity distribution. Hence, PCM model is very sensitive to initialization and need of additional parameters [36, 40]. Afterward a possibilistic-fuzzy clustering (PFCM) model is proposed. In PFCM algorithm both FCM and PCM model combined by introducing two new parameters a and b, where a and b are the weighting factors of FCM and PCM, respectively, to resolve the outlier problems of FCM and sensitivity problem. Again, in PFCM algorithm as it requires selecting additional parameters and extra computation complexity, a new model intuitive fuzzy c-means (IFCM) model is proposed by Dong-Chul Park for MRI image segmentation. The basic operation of IFCM model is same as in FCM except the membership assignment condition. To deal with the problems of membership assignment to noise data IFCM algorithm has been developed. In IFCM, a new measurement called intuition level is introduced by using membership values of FCM and PFCM, uki so that the intuition levels may alleviate the effect of noise data.

3. **Edge Detection:** For doing the segmentation by using edge detection approach, first step is to extracts the features by obtaining the information from images. Edge detection is a fundamental tool used in most image processing application. It is the process of detecting boundaries between objects and the background in the image, at which the image brightness changes sharply. There are many algorithms to perform edge detection, and all of them classified into two categories Gradient and Laplacian.

   Edge detection based on Gradient method initially calculates first derivative of image, and then find its corresponding local maxima and minima values to detect the edges. While, in the Laplacian method after obtaining the second derivative of the image it looks for zero crossing. There are various operators defined i.e. Roberts [41], Prewitt [42], Sobel [43], Canny [44] edge operators to perform Gradient method. These operators include a small kernel rolled up together with the image, which helps in estimating first order directional derivative of the image brightness distribution. This kernel finds edge strength in the direction, which are orthogonal to each other, usually vertically and horizontally. The total value of the edge strength is then obtained by the combination of both the components. Here by creating a matrix centered on each pixel it calculates the edge value. Moreover, if the calculated value is larger than provided threshold, then that pixel is classified as an edge.

With reference to the earlier work of the Marr and Hilderth [42], John F. Canny [44] has developed an edge detection operator named as Canny edge detection operator in 1986. This operator helps in detecting wide range of edged in images by using a multi-stage algorithm. He provided gradient-based-finding algorithm called as optimal edge detector, which becomes most popular and commonly used edge detectors to have the segmented image. Canny edge detector used a method called Hysteresis, which is proposed to tracing the unsuppressed pixels. Here it uses two threshold values i.e. high and low. After finding the gradient values, algorithm compares these values with the provided two threshold values. The pixel is set to zero if gradient value is below the low threshold value and if it is above the high threshold value then pixel is set as an edge. In case if, the gradient value is in between the two threshold values by default that pixel is set to zero (regarded as non-edge) although there is a path from that pixel to the pixel having gradient value above the high threshold value.

3.1.2 Computed Tomography (CT)

Computed Tomography (CT) scanning sometimes called Computed Axial Tomography (CAT) scanning [29], is a noninvasive medical test that helps physicians diagnose and treat medical conditions. CT scanning combines special x-ray equipment with sophisticated computers to produce multiple images or pictures of the inside of the body. These cross-sectional images of the area being studied can then be examined on a computer monitor, printed or transferred to a CD. CT scans of internal organs, bones, soft tissue and blood vessels provide greater clarity and reveal more details than regular x-ray exams. Using specialized equipment and expertise to create and interpret CT scans of the body, radiologists can more easily diagnose problems such as cancers, cardiovascular disease, infectious disease, appendicitis, trauma, and musculoskeletal disorders. Hence, the CT scan application is been widely used in medical domain. There are different segmentation methods proposed considering CT scan of different body organs (such as lung, liver, kidney, etc.) This section covers the different segmentation algorithm for CT scan images for protecting the distortion of diagnosis value.

The 2-D and 3-D segmentation of organs in medical application of image processing are classified into model based and nonmodel based approaches. Nonmodel based approaches depends on local information such as, texture, intensity, spatial correlation of 2-D organ image in consecutive slices, and the location of the organ in the abdominal area with respect to neighboring structures, e.g., spine and ribs [45]. Various segmentation algorithms are developed using nonmodel-based approach. This section first covers the different segmentation algorithm, which uses nonmodel-based approach. Susomboon et al. [46] presented texture features to perform region classication for extracting livers soft tissue. Seo et al. [47] employed a multimodal threshold method based on piecewise linear interpolation that used spine location as a reference point. Forouzan et al. [48] introduced a multilayer threshold technique, in which by statistical analysis of the liver intensity it calculates the threshold value. Both these methods use the local information of the livers relative position to the spine and ribs. Nonmodel-based methods for organ segmentation leads to inaccuracies due to variation in imaging condition, because of occurrence of tumor inside the organ and noise. Dependencies on prior information such as texture and image values could cause inaccuracies in segmentation process as feature could change from one patient to another. Moreover, most of these methods are parameter dependent and hence for the best performance it often needs to adjust the parameters from one CT volume to other. In recent years, model-based image segmentation algorithms developed for various medical applications. These methods aim to recover an organ based on statistical information. State-of-the-art algorithms on model-based segmentation are based on active shape and appearance models [45]. Model-based techniques provide more accurate and robust algorithm for segmenting the CT scan image. These techniques also deal with the missing image features via interpolation. The performance of these methods depends on the number and type of training data. Moreover, if the shape to be segmented lies too far from the model space, that might not be detected by many those better methods which does not implemented by statistical model-based approach.

Pan and Dawant [49] reported a geometrical-level set method for automatic segmentation of the liver in abdominal CT scans without relying on the prior knowledge of shape and size. Even if this method depends on a model-based technique, that outperforms threshold-based techniques, but it did not use prior knowledge of the liver shape. Lin et al. [51] presented the algorithm to perform segmentation of kidney, based on an adaptive region growing and an elliptical kidney region positioning that used spines as landmark. H. Badakhshannoory and P. Saeedi [51] incorporated a method for liver segmentation. Based on liver boundary edges to identify liver regions, nonrigid registration and a multilayer segmentation technique are combined in this approach. This method is does not affected by the diversity of existing liver shapes, as it does not rely on any shape model. Samuel et al. [52] has proposed the use of Ball-Algorithm for the segmentation of lungs. In this algorithm at the first stage, it applies the grey level thresholding to the CT images to segment the thorax from background and then the lungs from the thorax. Then in the next step to avoid loss of juxtapleural nodules, this method performs the rolling ball algorithm. Julian Ker [53] has presented the method of doing segmentation of lungs, which is named as TRACE method. Due to the possible presence of various disease processes, and the change of the anatomy with vertical position results in variation of size, shape, texture of lungs CT image of different patients. Therefore, the boundary between lung and surrounding tissues can vary from a smooth-edged, sharp-intensity transition to irregularly jagged edges with a less distinct intensity transition. The TRACE algorithm implemented with new perception of a non-approximating technique for edge detection. Shiying et al. [54] have introduced a fully automatic method for identifying lungs in 3D pulmonary X-Ray CT images. The method follows three main steps:

- lung region is extracted from CT-Scan image by applying graylevel thresholding,
- by using a dynamic programming it identifies the anterior and posterior junction, to separate left and right lungs and
- to smooth the irregularities of boundary along the mediastinum nodule, it implements sequence of morphological operations

Ayman El-Baz et al. [55] have employed a fully automatic Computer-Assisted Diagnosis (CAD) system for lung cancer screening using chest spiral CT scans. This paper presents a system for detection of abnormalities, identification or classification of these abnormalities with respect to specific diagnosis, and provides the visualization of the results over computer networks. The process of detection of abnormalities, identification of these abnormalities can achieve by image analysis system for 3-D reconstruction of the lungs. Riccardo Boscolo et al. [56] proposed method that uses the novel segmentation technique that combines a knowledge based segmentation system with a sophisticated active contour model. This method performs robust segmentation of various anatomic structures. In this approach the user, need to provide initial contour placement, and the required parameter optimization automatically determined by the high-level process. Binsheng et al. [57] reported the algorithm, which used the method of selecting the threshold value by analyzing the histogram. This algorithm initially separates the lung parenchyma from the other anatomical structures from the CT images by using threshold value. By this algorithm structure in CT scan image with higher densities having some higher density nodules, can grouped into soft tissues and bones, leading to an incomplete extraction of lung mask. For having complete hollow free lung mask, morphological closing is applied in this approach. Hossein B. et al. [45] has introduced the model-based segmentation algorithm. In this approach instead of using model information to direct the segmentation algorithm for segmenting an organ of CT scan images, it uses this information to choose a segment with highest fidelity to the organ.

After completing with the segmentation of ROI, needs to proceed with medical image watermarking technique to provide security, authentication and privacy of this medical data. The next section of this paper provides the survey of different available medical image watermarking approaches.

3.2 Medical Image Watermarking

There has been fair amount of work done in the area of medical image processing. Numbers of medical image watermarking schemes are reported in this literature survey, to address the issues of medical information security, and authentication.

Wakatani [58] presented a medical image watermarking, in order not to compromise with the diagnosis value, it avoids embedding watermark in the ROI. In this algorithm watermark to be embed is firstly compressed by progressive coding algorithm such as Embedded Zero Tree Wavelet (EZW). Embedding process is done by applying Discrete Wavelet Transform (DWT), for transforming the original image using Haar basis. Extraction of watermark is reverse of embedding process. The major drawback of this algorithm is ease of introducing copy attack on the non-watermarked area. Yusuk Lim et al. [59] reported a web-based image authentication system, they used the CT scan images. This technique is mainly based on the principal of verifying the integrity and authenticity of medical images. In this approach, the watermark is preprocessed by using 7 most significant bit-planes except least significant bit (LSB) plane of cover medical image, as a input to the hash function. This hash function generates binary value of 0 or 1 using secrete key, which is then embedded in LSB bit of cover image to get watermarked image.

Rodriquez et al. [60] proposed a method in which it searches a suitable pixel to embed information using the spiral scan that, starts from the centroid of cover image. Then by obtaining the block with its center at the position of selected pixel, it checks the value of bit to embed. If bit value is 1, then the embedding information is obtained by changing the luminance value of the central pixel by adding the gray-scale level mean of the block with luminance of the block. In addition, if bit value is 0, then luminance value of the central pixel is changed by subtracting the luminance value of block from the gray-scale level mean of the block. While in extraction process, the position of marked pixel is obtained by spiral scan starting from centroid of the cover image. By checking the luminance value of the central pixel with the gray-scale level mean of the block, embedded bit is identified. Giakoumaki et al. [20] presented a multiple watermarking method using wavelet-based scheme. The method provides solution to the number of medical data management and distribution issues, such as data confidentiality, archiving and retrieval, and record integrity. In this approach up to 4 level DWT is performed on medical image. The algorithm embeds multiple watermarks in different level. A robust watermark containing doctors identification code is embedded in 4th level as here capacity is not the matter, only required is the robustness. In third level decomposition, the index watermark (e.g ICD-10 or ACR diagnostic codes) is embedded. The method embeds caption watermark holding patients personal information in second decomposition level. Moreover, a fragile watermark is embedded in forth-level decomposition. Extraction process is reverse of embedding process. Experimentation is done on ultrasounds medical images.

Hemin Golpira et al. [61] reported reversible blind watermarking. In this approach during embedding process, firstly by applying Integer Wavelet Transform (IDWT) image is decomposed into four subbands. By selecting two points, called thresholds, according to the capacity required for the watermark data, watermark is embedded. To get watermarked image Inverse Integer Wavelet Transform (IIDWT) is applied. In the extraction process, all of these stages are performed in reverse order to extract watermark as well as host image.

Nisar Ahmed Memonet et al. [62] presented fragile and robust watermarking technique for medical images. The method embeds two different watermarks, the robust watermark and fragile watermark in the medical images. The embedding process is start with separation of ROI and RONI from medical images. The robust watermark containing the electronic patient record (EPR), Doctors identification code (DIC) and 1st bit-plane of ROI by extracting the LSBs is encrypted by using pseudo random sequence generated by user defined key. Then this resultant watermark is embedded in high frequency coefficient of IWT in RONI part of medical data. The proposed method generates fragile watermark by creating the binary image in tiled fashion and then this fragile watermark is cropped off by the same size as the ROI. The algorithm embeds this fragile watermark into spatial domain of ROI part of medical image. The extraction process is reverse of embedding process.

Chapter 4

Proposed System for Medical Image Watermarking preserving ROI

Our approach focuses on embedding watermark in RONI region of medical image by preserving ROI. This approach helps in isolating ROI region i.e. not to distort the critical area of medical image, which will be referred by physician for the diagnosis. The system diagram for this approach is shown in Figure 4.1. The system process carried away in three stages:

1. Watermark embedding process
2. Watermark extraction process
3. Watermark authentication process

In first phase of system separating the ROI from the original medical image provides RONI region for embedding watermark. This step isolates ROI from embedding process. In this phase multiple watermarks are embedded into the RONI area of medical image. Embedding multiple watermarks ensure high security of medical image as it carries high payload and it will be more complex to break the system. Here fragile watermarking system is used to get the benefit of identifying whether a medical image is tampered or not?

After the completion of embedding process the separated ROI is combined with the produced watermarked medical image. The resultant watermarked medical image is then sent to the receiver.

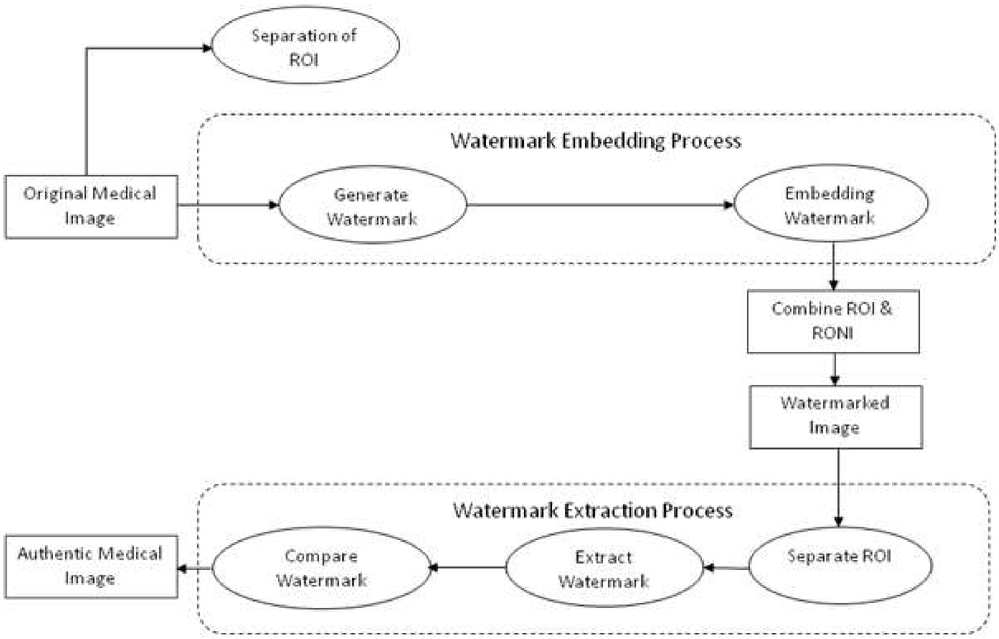

Figure 4.1: Medical Image Watermarking Approach Preserving ROI

In watermark extraction phase, first step is separating the ROI from the watermarked medical image. The remaining watermark extraction process is exact reverse of embedding process, where the embedded watermark will be extracted from the watermarked medical image. The watermark authentication is achieved by comparing the extracted watermark with the original watermark. This process helps in identifying if any tampering or manipulation to the watermarked medical image over the public network.

4.1 Separating ROI from medical image

As discussed earlier for separating ROI Segmentation method is used. However segmentation is semi-automatic procedure and it needs to define a seed point in an image. Therefore, the algorithm, which gives perfect result for one type of application, may not even work for another.

In proposed system for separating ROI the Graphical User Interface (GUI) is implemented, so that it will work for all kinds for medical image (such as CT scan, MRI, X-Ray, Ultrasound, etc.). The interface for the implemented GUI based approach is shown in Figure 4.2. In this method user has an option to select the part of medical image (square in size) which has critical information and used for the reference of physician. This GUI based system returns the Xmin,

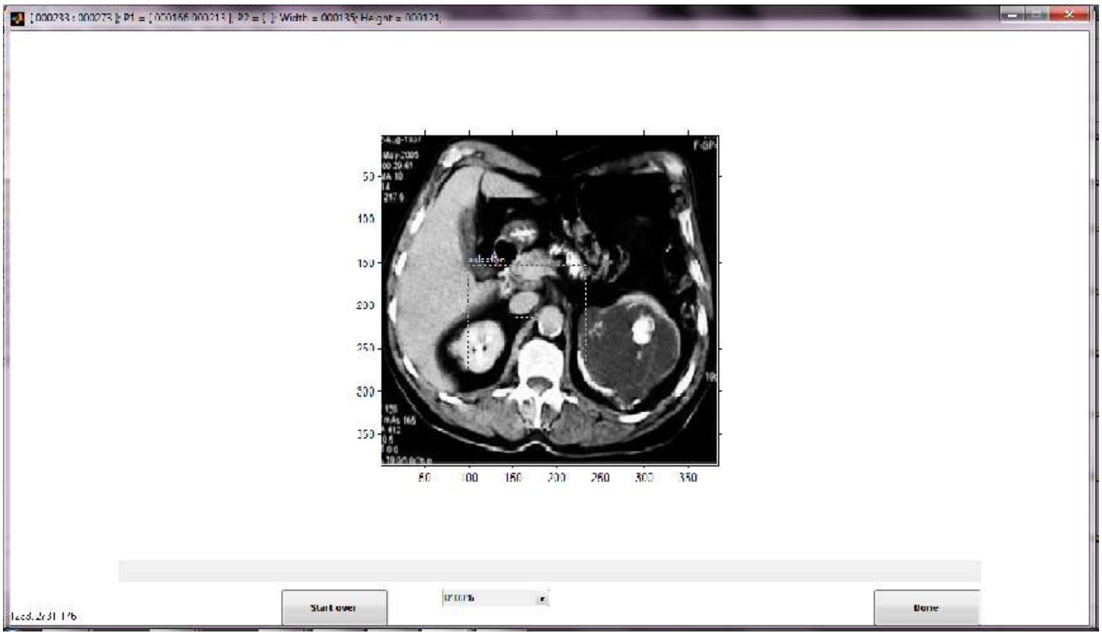

Figure 4.2: Interface for GUI based approach

Xmax, Ymin, Ymax pixel values of selected ROI region and image of selected ROI. This resulted ROI image can be saved, so that it can be combined with the resultant watermarked image. The dashed square in Figure 4.2 is the user selected ROI of medical image, the region that can be selected by mouse click function. The respective pixel values (Xmin, Xmax, Ymin, Ymax) are shown at top of the window panel.

Steps in ROI separation approach

- Mouse click function: For selecting the ROI, mouse clicking function is used.
- Done button: To get the output after selection process, done button is implemented.
- Storing handles: For safe storing the pixels values of selected ROI (Xmin, Xmax, Ymin and Ymax) and image of selected ROI, the storing handles are use.
- Start button: It is implemented to clear the stored handles to start again the process of selecting ROI.
- Zooming option: It is provided for zooming the image, so that the image will be clear to select the ROI.

4.2 Medical Image Watermarking System

For the implementation of Medical Image Watermarking, we referred the algorithm proposed by Giakoumaki et al. [20]. The algorithm provides solution to the number of medical data management and distribution issues, such as data confidentiality, archiving and retrieval, and record integrity. The medical watermarking system embeds the multiple watermarks. The watermarks used to embed are in the text form. In this approach medical image is decompose with 4-level lifting based DWT transform. The lifting based DWT is a better method to obtain the wavelet transform. For the development of second generation wavelet the lifting based DWT approach is proposed. Advantage of second generation wavelet over first generation wavelet is that, it does not use the translation and dilation of the same wavelet prototype in different levels. Using the Euclidean algorithm any classical wavelet filter bank can be decomposed into lifting steps. The lifting based DWT consists of three stages i.e. split, predict and update. In split stage the input signal x[n] get divided into two subsets i.e. even set s[n] and odd set o[n]. This process is known as lazy wavelet transform. The predict step use the linear combination of elements in one subset to guess the values of the other subset with assumption that the subsets produced in the split stage are correlated with each other. The predicted values would be close to the original values if the correlation between both the subset is high. Generally the linear combination of the even subset elements are used to predict odd subset values. The predict step is defined as:

$$d[n] = o[n] - \sum_{k} p[k]s[n-k] \tag{4.1}$$

Where d[n] is the difference between the actual values and the predicted values, P[k] is prediction coefficient. Although there are chances of loss of properties of signal such as mean value in the predict step.

$$s1[n] = s[n] - \sum_{k} u[k]d[n-k] \tag{4.2}$$

The predict step causes the loss of some basic properties of the signal like mean value, which needs to be preserved. The update step lifts the even sequence values using the linear combination of the predicted odd sequence values so that the basic properties of the original sequence is preserved [5]. The even sequence values s1 obtained as the result of equation 4.2 is equivalent to the sub-sampled low pass version of the original sequence.

4.2.1 Integer to Integer transform

It was observed that usually when wavelet transforms is performed on integer sequence it gives floating point coefficients. As per Calderbank [6] wavelet transform which will map integers to integers can be build with the help of lifting structure. This can be achieved by rounding off or updating the filter in each lifting step before its addition or subtraction. The invert of the lifting steps can be produced by following the exact reverse operation and flipping the signs.

4.3 Method

In recent days the wavelet analysis got a good recognition in research and development area due to its characteristic of providing time and frequency information simultaneously. As per research the retina of the eye splits an image in to several frequency channels i.e. approximately one octave. In multi resolution decomposition, the image is divided into bands of equal bandwidth on a logarithmic scale. There is lot of similarity between the signal processing of the human visual system (HVS) and scaling decomposition of the wavelet transform, which can be achieved by watermark embedding to the masking property or quantization method [7].

4.3.1 Description

The watermarks used in this approach:

1. Doctor's identification code
2. Indexed watermark
3. Patient's reference identification code
4. Patient's diagnosis information
5. Patient's treatment information

The listed watermarks used in this proposed watermarking scheme helps in addressing different issues and concerns in healthcare management system, Such as confidentiality of medical data, recovering original image without any distortion, data integrity, authentication and efficient data management.

Confidentiality of medical data is achieved by embedding watermark using Integer to Integer Discrete Wavelet Transform (IDWT), which confirms the imperceptibility property. This property ensures the embedded watermark will be invisible to the normal human eye and the watermark can be extracted by the one who knows the embedding and extraction algorithm applied in this system. By applying Inverse IDWT at the receiver end original image can be recovered without any distortion. Also the distortion to the ROI has already been avoided by separating the ROI before embedding the watermark in to the medical image. Medical data integrity is achieved by using fragile watermarking system, so any manipulation on medical image data leads in distortion of embedded watermark. For the authentication purpose the included watermarks such as doctor's identification code, patient's identification code will ensures the entitled users can access or modify the medical data. To provide efficient data management in this system the indexed watermark is embedded which helps in retrieving the image for the future reference if needed using database query.

The watermarks are inserted in different decomposition levels and sub-bands depending on their type. They can be independently embedded and retrieved without any intervention among them. By integrating this idea in to different medical acquisition systems like Ultrasound, CT and MRI etc. This system can be applied in different applications such as e-diagnosis or medical image sharing through picture archiving and communication.

Selection of embedding coefficient

The Figure 4.3 illustrates the subband structure of a 4-level harr wavelet decomposition of an original medical image, which is obtained after removing the ROI from the host medical image. This decomposed image comprise of a coarse scale image approximation at the highest decomposition level i.e. at 4th level, and it also contains the twelve detail images corresponding to the horizontal (HL), vertical (LH), and diagonal (HH) details at each of the 4-level.

The watermark holding the doctor's identification is the most important for the identification purpose and are of limited in length hence capacity is not very important. By considering this two points this doctor's identification code containing watermark is embedded in the fourth level, because more the decomposition level more the robust watermark. On the other hand index watermark and patient's identification code requires more space than the doctor's identification code since they pass on many bits of additional information. The index watermark holds the decomp.png

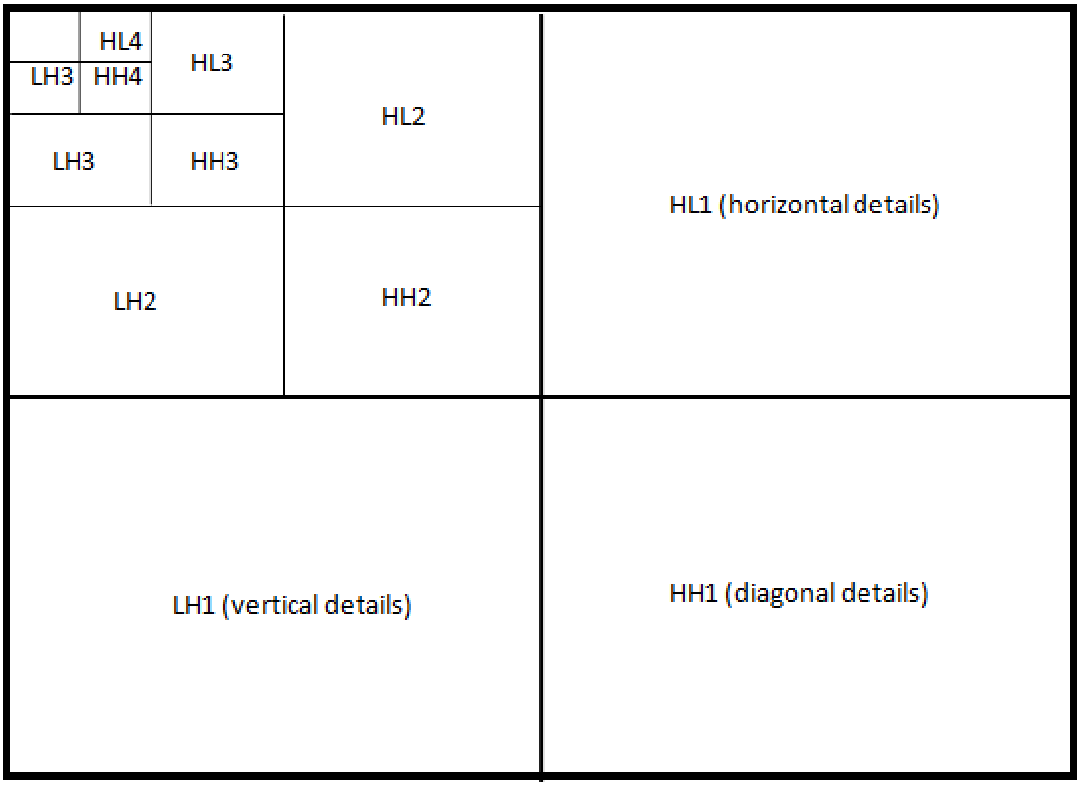

Figure 4.3: Sub-band structure a of 4-level wavelet transform

information, which is used to retrieve the medical image. So the required capacity for this watermark lies between the degrees of capacity intended for patient's identification code, patient's diagnosis information, and treatment information. Focusing on the above fact indexed watermark is embedded into third decomposition level. The watermark contain patient's identification is embedded into 2nd decomposition level as it requires less space than both diagnosis information watermark and treatment watermark. The patient's diagnosis information watermark and patient's treatment information watermark both requires the more capacity so these fragile watermarks are embedded into 1st level. If any modification or tampering to the embedded image occurs then the extracted watermark will be totally different than embedded one.

In general horizontal and vertical sub-bands are used to embed the watermark, as they have more or less same behavior in contrast to diagonal one. By embedding the watermark into horizontal or vertical details coefficients results in less distortion of image. Especially for the ultrasound images the energy of horizontal details is more than compare to the vertical and diagonal details. This is due to

Table 4.1: **Energy of Approximation and Detail Images of Four Level DWT**

Sub-bands	Level 1	Level 2	Level 3	Level 4
Approximation				41.4514
Horizontal	5.4363	8.8305	14.8038	16.9878
Vertical	4.5678	7.2816	9.0938	10.4323
Diagonal	3.3392	5.6763	9.3863	12.5729

the elongation of ultrasound image mark spots in the horizontal direction [57]. For all other medical images the energy of horizontal and vertical details are approximately same. Table 4.1 shows the energy of the approximation and detail images for a 4-level haar wavelet decomposition of an ultrasound test image shown in Figure 4.4.

Figure 4.4: Ultrasound Image

From the table 4.1, it is clear that at the higher decomposition level corresponding to the low frequency coefficients have the more energy than the energy bat the lower decomposition level. Moreover the energy of horizontal details sub-band is more than the energy of vertical and diagonal details sub-band. Hence the watermarks are embedded into horizontal sub-bands in this system. As the approximation sub-bands LL4 has most energy of the medical image and has the huge amount of impact on the quality of medical image, it is not used for embedding purpose to retain imperceptibility.

The energy of the approximation and detail images obtained by four-level DWT can be calculated as:

$$e_k = \frac{1}{N_k M_k} \sum_i \sum_j |C_k\,(i,j)| \tag{4.3}$$

Where k is the approximation and detail images at each of the decomposition levels, Ck are the coefficients of the sub-band images, Mk and Nk are their corresponding dimensions.

4.3.2 Algorithm

In this algorithm the multiple watermarks embedding technique is used. Where, depending on the quantization of selected coefficients the multiple watermarks embedding procedure is used. This prevents any modification to the watermark bits by granting integer changes in spatial domain of medical image. This can be achieved by applying 4-levl haar wavelet transform to decompose the host medical image. Moreover it gives the output as coefficients, which are in the form of dyadic rational numbers. These coefficients denominators are in powers of 2. The multiple of 2^l (l is decomposition level) number adding or subtracting to the produced coefficient value, assures that the inverse DWT provide integer pixel values. Wavelet transform generally provides the coefficients which are real numbers. By applying the quantization function it assigns the binary number to every coefficient. This quantization function is defined as

$$Q(f) = 0, \quad if \left\lfloor \left(\frac{f-s}{\Delta} \right) \right\rfloor is\ even \tag{4.4}$$

$$Q(f) = 1, \quad if \left\lfloor \left(\frac{f-s}{\Delta} \right) \right\rfloor is\ odd \tag{4.5}$$

Where s is a user-defined offset for increased security, f is frequency coefficient produced by haar wavelet transform and , the quantization parameter, is a positive real number. Moreover Δ is defined as $\Delta = 2^l$. The quantization procedure is shown in Figure 4.5.

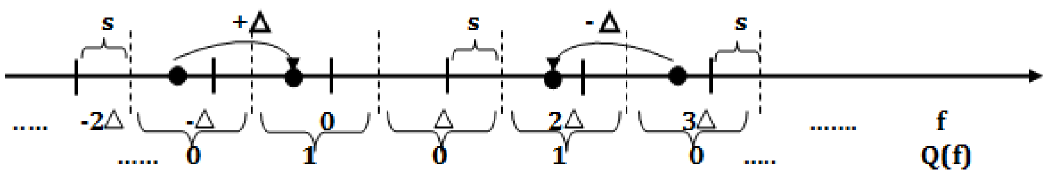

Figure 4.5: Quantization Procedure

As explain earlier, addition or subtraction of a multiple of 2^l value to the haar wavelet coefficient results in integer pixel values, after applying inverse DWT. During the embedding process the algorithm add or subtract an appropriate constant to the haar coefficient chosen for watermark casting.

The algorithm for embedding multiple watermarks is explained below:

Step 1: Separate the ROI region from the host medical data using GUI based

mouse clicking approach. Which results in image of RONI region, name it as original medical image.
Step 2: Save the removed ROI from medical image.
Step 3: The multiple watermarks to be embed into a original image is generated by reading the patient's information file from text document, and converting it into binary.
Step 4: Apply the 4-level Haar-lifting wavelet transform to original medical image, to obtained a gross image approximation at the lowest resolution level and a sequence of detail images corresponding to the horizontal, vertical, and diagonal details at each of the four decomposition levels.
Step 5: On each decomposition level the watermark bit wi is embedded into the key determined coefficient f, which is obtained by applying wavelet transform according to the following condition:

1. If Q(f) $= w_i$, the coefficient is not modified
2. Otherwise, the coefficient is modified so that Q(f) $= w_i$, using the following equation:

$$f = f + \Delta, \quad if \quad f \leq 0 \tag{4.6}$$

$$f = f - \Delta, \quad if \quad f > 0 \tag{4.7}$$

Step 6: The pre watermarked image is produced by performing the corresponding four level inverse wavelet transform.
Step 7: The resultant watermarked image is obtained by combining the saved ROI with the pre watermarked image.

The watermark extraction process is similar to that of embedding one except that at the receiving end extractor should have the knowledge of location of the embedded watermark. This can achieve by the key-based embedding and detection. With this type of method access to the watermark by unauthorized users is prevented. The algorithm for extraction process to recover the host medical image is explained below.
Step 1: Remove the ROI region from the received watermarked image with the help of Xmax, Xmin, Ymin and Ymax parameter provided with watermarked image.
Step 2: Apply the 4-level lifting-haar wavelet transform to the image which is created from step 1, which results in a image approximation at level four and sequence of images corresponding to the horizontal, vertical, and diagonal details

at each of the four decomposition levels.

Step 3: Identify the location of watermark by key-based detection.

Step 4: Extract the watermarks by applying quantization function defined in equation 4.4 and 4.5, which recovers the original coefficient. Convert the extracted binary watermark to text watermark.

Step 5: The pre output image is obtained by applying inverse 4-level haar wavelet transform.

Step 6: combine the separated ROI region to the pre output image to get the original host medical image.

Chapter 5

Experiments and Results

The proposed system has been applied against different type of medical image such as, CT scan, MRI, X-Ray and Ultrasound. We have tested the system over different size of medical images like 320 X 256, 384 X 384, and 512 X 512.
The applied watermark was consists of in

1. **Doctor's identity:** G123468
2. **Indexing for database:** 321-123.1
3. **Patient's identification:** sonika_c_rathi.190.85.04567851
4. **Diagnosis Information:** light.sugar_healthy_extra.spicy_no.fats_12189.75.1
5. **Treatment applied to the patient:** painkiller.hgkkfgjklfd_abcdefmglkh_bkjdhflkds.yeio

The results after applying the system against CT scan, MRI, X-Ray and Ultrasound are shown below:

5.1 The experiments and results of the system without attacks

5.1.1 CT Scan Images

The embedded and extracted watermark values are shown in Figure 5.4, with PSNR value (p) and MSE (d).

The system is applied on different CT scan images considering their image size and noted corresponding results, which are shown in table 5.1. The table shows the PSNR value for ROI extracterd from host image and ROI extracted

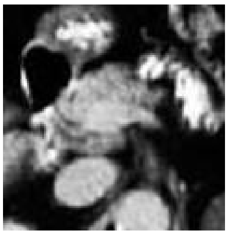

Figure 5.1: Segmenatted ROI of host image

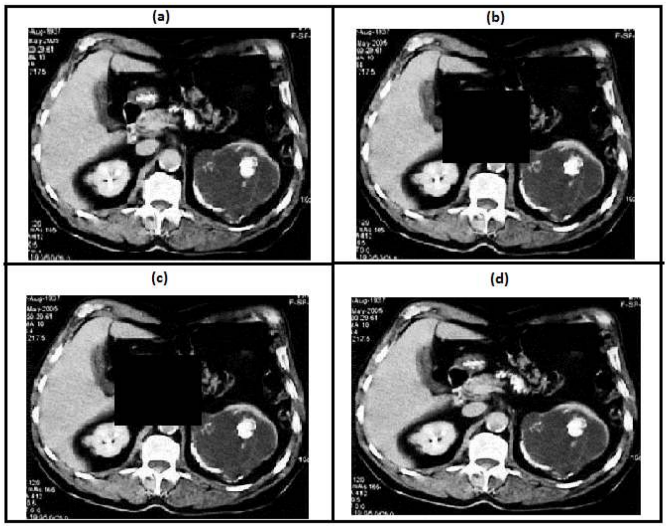

Figure 5.2: (a) The original host CT scan image, (b)Roi removed image,(c)Emebedded image without ROI, (d)Final embedded image with ROI

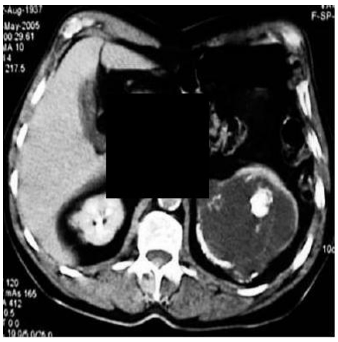

Figure 5.3: Recovered original image

from watermarked image. As the corner pixel values of ROI image is changed the PSNR is not ∞ but there correlation is approximately 1. So, the selected ROI should be large enough to not compromise with the diagnosis value. The table also provides the PSNR value for embedded image and original image and there respective mean square difference.

```
Embedding watermark value

DocID G123468
IIdx 321-123.1
PatRef sonika_c_rathi.190.85.04567851
Diag light.sugar_healthy_extra.spicy_no.fats_12189.75.1
Trtmt painkiller.hgkkfgjklfd_abcdefmglkh_bkjdhflkds.yeio

Extracted watermark value

DocID G123468
IIdx 321-123.1
PatRef sonika_c_rathi.190.85.04567851
Diag light.sugar_healthy_extra.spicy_no.fats_12189.75.1
Trtmt painkiller.hgkkfgjklfd_abcdefmglkh_bkjdhflkds.yeio

d =

    4.0059


p =

   42.2390
```

Figure 5.4: Embedded and extracted watermark values without any attacks

Table 5.1: Results of CT scan images

Size	MSE	PSNR	PSNR extracted ROI	Correlation between the ROI
320 X 256	6.81	39.83	38.69	0.9963
384 X 384	4.00	42.23	43.20	0.9994
512 X 512	2.11	44.71	45.12	0.9998

5.1.2 MRI Images

The embedded and extracted watermark on the MRI image shown in Figure 5.5 (a), are given in Figure 5.6.

The results after applying the system on different size of MRI images are shown in table 5.2.

Table 5.2: Results of MRI images

Size	MSE	PSNR	PSNR extracted ROI	Correlation between the ROI
320 X 256	6.86	39.40	37.24	0.9962
384 X 384	3.84	42.28	41.20	0.9993
512 X 512	2.22	44.70	44.12	0.9998

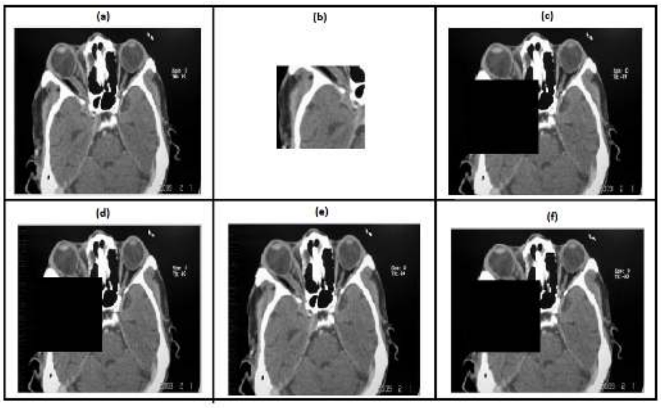

Figure 5.5: (a) The original host MRI image, (b)ROI image of host image,(c)Roi removed image (c)Emebedded image without ROI, (d)Final embedded image with ROI

, (e)Recovered image

```
Embedding watermark value

DocID G123468
IIdx 321-123.1
PatRef sonika_c_rathi.190.85.04567851
Diag light.sugar_healthy_extra.spicy_no.fats_12189.75.1
Trtmt painkiller.hgkkfgjklfd_abcdefmglkh_bkjdhflkds.yeio

Extracted watermark value

DocID G1233ö?
IIdx 321-123.1
PatRef sonika_c_rathi.190.85.04567851
Diag light.sugar_healthy_extra.spicy_no.fats_12189.75.1
Trtmt painkiller.hgkkfgjklfd_abcdefmglkh_bkjdhflkds.yeio

d =

    6.7417


p =

   39.8771
```

Figure 5.6: Embedded and extracted watermark values without any attacks for MRI image

5.1.3 X-Ray Images

The embedded and extracted watermark on the X-Ray image shown in Figure 5.7 (a), are given in Figure 5.8.

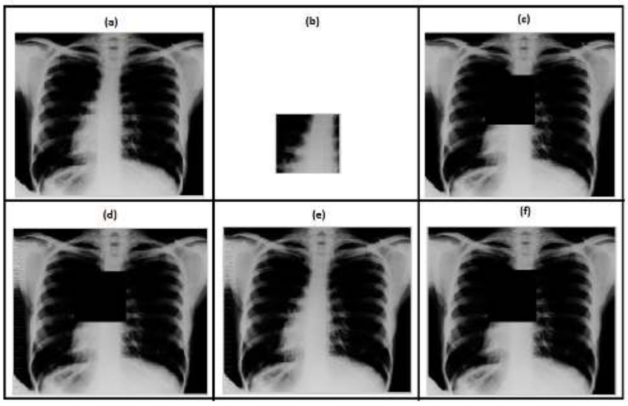

Figure 5.7: (a) The original host X-Ray image, (b)ROI image of host image,(c)Roi removed image (c)Emebedded image without ROI, (d)Final embedded image with ROI

, (e)Recovered image

```
Embedding watermark value

DocID sonika_rathi
IIdx 460-512.2
PatRef sonika_c_rathidnfksdgjigsj
Diag normal_diaetdghbjkbfkjsdlfsdjlkjglkdjgbdjgksdkjglksdj
Trtmt painkillerndshhvsdijgidjis

Extracted watermark value

DocID sonika_
IIdx 460-512.2
PatRef sonika_c_rathidnfksdgjigsjþ?ÿÿ
Diag normal_diaetdghbjkbfkjsdlfsdjlkjglkdjgbdjgksdkjglk
Trtmt sdjpainkillerndshhvsdijgidjisÿý ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿù ÿÿ

d =

    5.7846


p =

   39.5360
```

Figure 5.8: Embedded and extracted watermark values without any attacks for X-Ray image

The results after applying the system against different size of X-Ray images are shown in table 5.3.

Table 5.3: Results of X-Ray images

Size	MSE	PSNR
320 X 256	6.93	39.60
384 X 384	3.92	42.18
512 X 512	2.16	44.63

5.1.4 Ultrasound Images

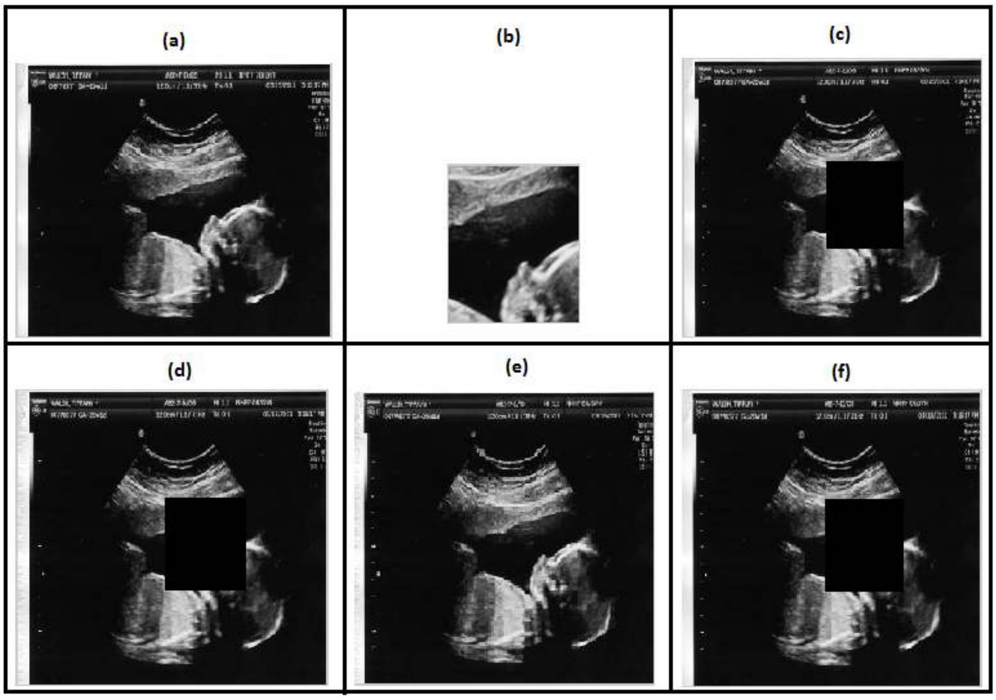

Figure 5.9: (a) The original host Ultrasound image, (b)ROI image of host image,(c)Roi removed image (c)Emebedded image without ROI, (d)Final embedded image with ROI

, (e)Recovered image

The embedded and extracted watermark on the Ultrasound image shown in Figure 5.9 (a), are given in Figure 5.10.

The results after applying the system against different size of Ultrasound images are shown in table 5.4.

5.2 Embedded and extracted watermark with attacks

The embedded and extracted watermark after applying different attacks on the watermarked images are shown in this section. The attacks applied on the water-

```
Embedding watermark value

DocID sonika_rathi
IIdx 460-512.2
PatRef sonika_c_rathidnfksdgjigsj
Diag normal_diaetdghbjkbfkjsdlfsdjlkjglkdjgbdjgksdkjglksdj
Trtmt painkillerndshhvsdijgidjis

Extracted watermark value

DocID sonika_
IIdx 460-512.2
PatRef sonika_c_rathidnfksdgjigsjÿÿÿÿ
Diag normal_diaetdghbjkbfkjsdlfsdjlkjglkdjgbdjgksdkjglk
Trtmt sdjpainkillerndshhvsdijgidjisÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ  ÿï

d =

    3.1191


p =

   43.9718
```

Figure 5.10: Embedded and extracted watermark values without any attacks for Ultrasound image

Table 5.4: Results of Ultrasound images

Size	MSE	PSNR
320 X 256	6.93	39.60
384 X 384	3.92	42.18
512 X 512	2.16	44.63

marked medical images are:

- Slat and pepper noise attack
- Cropping attack
- Histogram equalization
- Sharpning attack
- Sampling attack
- JPEG compression attack

The following figures shows the attacked watermark medical image and embedded, extracted watermark of CT scan, MRI, X-Ray and Ultrasound images:

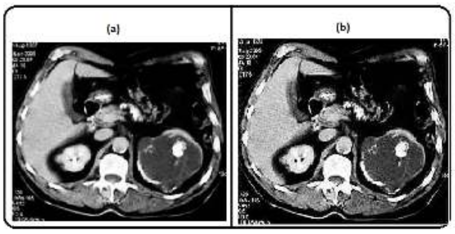

Figure 5.11: (a) The original watermarked CT scan image, (b)The image after sharpning attack with 0.02 factor

The extracted watermark from the attacked CT scan image is shown in Figure 5.12. The sharpning attack with 0.02 factor is applied on watermarked CT scan image, shown in Figure 5.11 (a).

```
Embedding watermark value

DocID sonika_rathi
IIdx 460-512.2
PatRef sonika_c_rathidnfksdgjigsj
Diag normal_diaetdghbjkbfkjsdlfsdjlkjglkdjgbdjgksdkjglksdj
Trtmt painkillerndshhvsdijgidjis

Extracted watermark value

DocID ¼ ¬idÝµ
IIdx @36Â  Ô|L
PatRef  [ÂÇ[4 ´»SoÌ  ©3/ ~LY Ý ÿ2Þ
Diag g÷ïH  Túnå °õh~`jcwyâ ø^üF¶ à
æaëUgâòå}l«w~àíMâÒçQ
Trtmt ® ; ý|Zû}k 3á»ìge}åó £  ên 4-  ÓWu(Ü*³?Àóñô Få¦

d =

  286.6299


p =

   23.5576
```

Figure 5.12: Embedded and extracted watermark values with sharpning attck (0.02 factor) image

The Figure 5.13 shows the original watermarked MRI image and the histogram attacked watermarked image. The embedded and extracted watermark values after histogram attack are given in Figure 5.14.

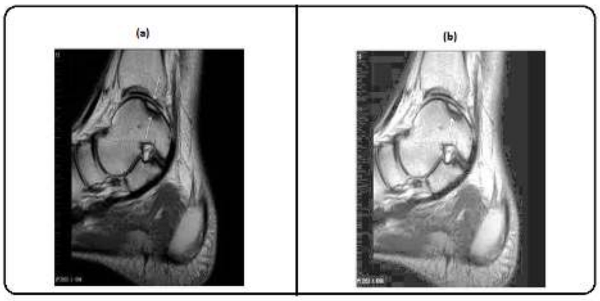

Figure 5.13: (a) The original watermarked MRI image, (b)The image after Histogram attack

```
Embedding watermark value

DocID sonika_rathi
IIdx 460-512.2
PatRef sonika_c_rathidnfksdgjigsj
Diag normal_diaetdghbjkbfkjsdlfsdjlkjglkdjgbdjgksdkjglksdj
Trtmt painkillerndshhvsdijgidjis

Extracted watermark value

DocID i2 DÂeÓ
IIdx ¼õ ÚÐ@  B
PatRef  pèé;´,X jj¨ )Ó_ z  Py¦9r þúýÖ
Diag hçO P= í  »vV?¶ÿS/yÄ)èM Ú ª ǻd × [(¶á_·Y qà Qø¡çãO-
Trtmt  ;\û¶é_ DÊìâM¬¹;Oéè ¤òU{¿æ]Ý ×} ýÝ åý  ?läÿ ÿ ÿÿýÚ

d =

  4.8387e+003


p =

   11.2835
```

Figure 5.14: Embedded and extracted watermark values after histogram attack on image

As, the algorithm implemented is fragile system, after even the 10% of jpeg compression to the X-Ray image, the extracted watermark from attacked image is totally distorted. This distortion of extracted watermark is shown in Figure 5.16, the original watermarked image and attacked image is shown in Figure 5.15.

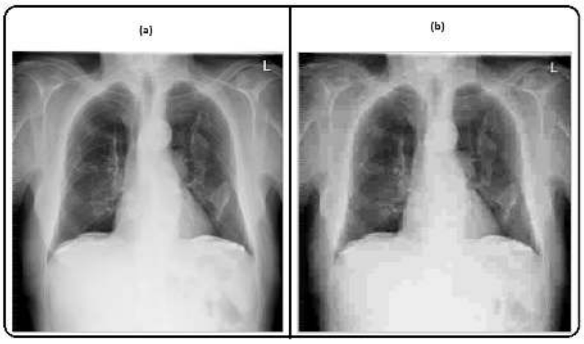

Figure 5.15: (a) The original watermarked X-Ray image, (b)The image after 10% JEPG compression attack

```
Embedding watermark value

DocID sonika_rathi
IIdx 460-512.2
PatRef sonika_c_rathidnfksdgjigsj
Diag normal_diaetdghbjkbfkjsdlfsdjlkjglkdjgbdjgksdkjglksdj
Trtmt painkillerndshhvsdijgidjis

Extracted watermark value

DocID ÃaòTz ì
IIdx ; *¤
PatRef ÿÃ×q>33ÏÿÿûóÿC× >73Ïÿÿûó ?ÿ/ÿÿ
Diag ÿOü
ù  ¿o¯oooooÿÿÿÿÿÿÿÿÿoÿoÿ
ù  ÿo¯oooooÿÿÿÿÿÿÿÿÿoÿo
Trtmt ÿ
ù  ÿÿ¯oooooÿÿÿÿÿÿÿÿÿoÿ)
ù  ÿ ¯oooooÿÿÿÿÿÿÿÿÿo¾ ÿÿ

d =

   24.9576


p =

   34.1588
```

Figure 5.16: Embedded and extracted watermark values after JEPG Compression attack on X-Ray image

The Figure 5.17 shows the original watermarked image and attacked watermarked image of ultrasound image. Here the Down and Up sampling attack is applied on watermarked ultrasound image. The attack is applied with 1 factor of down sampling and 1 factor of up sampling on the watermarked image. The Figure 5.17 clearly shows that both the images are look like same, that is by normal human eye the difference between the two image is not visible. However the extracted watermark from the attacked image is totally different than the embedded one. The embedded and extracted watermark values are shown in Figure 5.18

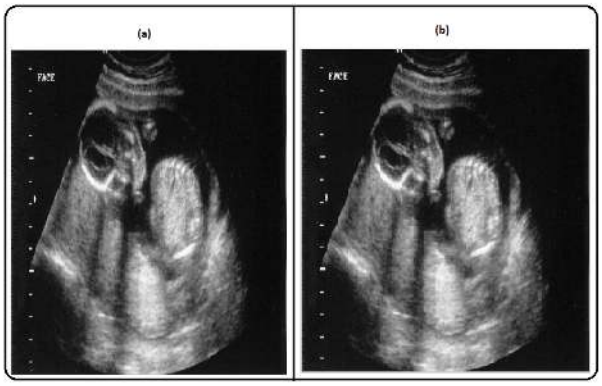

Figure 5.17: (a) The original watermarked Ultrasound image, (b)The image after up and down sampling attack

```
Embedding watermark value

DocID sonika_rathi
IIdx 460-512.2
PatRef sonika_c_rathidnfksdgjigsj
Diag normal_diaetdghbjkbfkjsdlfsdjlkjglkdjgbdjgksdkjglksdj
Trtmt painkillerndshhvsdijgidjis

Extracted watermark value

DocID q/'lkaO
IIdx ~Iø¥t 072
PatRef s/fiKa_c_p`tkmdndksdg*mf{júÿÿÿ
Diag n¯3C¡j¾loAUt!Ac-&ªde{lcc| ulJoKjozótdodeñ'åòäuâvt
Trtmt `mnachMgqìEmäf zHh¶óGmê§MxMaIWÿ óíî~có
ÿ{ï ðÿný)Á

d =

    1.7765


p =

   45.6351
```

Figure 5.18: Embedded and extracted watermark values after down and up sampling attack on Ultrasound image

Chapter 6

Conclusion and Future Work

6.1 Conclusion

There exist various medical image watermarking algorithms which provide the confidentiality of medical data, recovering original image without any distortion, data integrity, authentication and efficient data management. Also the different segmentation algorithms are in place, which vary for the types of medical images such as MRI, CT scan, X-ray and Ultrasounds etc.

Here the proposed system used an algorithm to separate ROI from the host medical image that will be applicable for all types of medical images. Separated ROI can be stored with xmin, xmax, ymin, and ymax value so that at the end of embedding process before transmitting watermarked image, the segmented ROI can be attached with watermarked image. And the ROI region which is considered as a critical data and used as a reference by the physician for the treatment will be safe.

6.2 Future Work

Proposed system uses DWT approach for embedding the watermark, instead of DWT use of Complex Wavelet Transform (CWT) will make the system more robust and secure.

The current proposed system can further be extended to provide more secured system. This can be done by encrypting the watermark using secret key, before embedding it in to medical images. Having the automated tool for separating the

ROI from medical image will provide faster system and more accurate system, which will be easier for end user.

The watermark before embedding can be compressed and then embedded. This will lead to more secured system. Also, it will take more effort to break the system.

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