Using Visible and Invisible Watermarking Algorithms for Indexing Medical Images

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Abstract: *Watermarking of medical images greatly helps to provide authentication for safe storage and transmission of image databases. Though proper methodologies for indexing the medical images would provide faster retrieval performance, the problems have not been greatly addressed in the literature. This paper presents a review on image watermarking algorithms for indexing medical images. We have attempted at embedding and extraction of both visible and invisible watermarking algorithms over a set of 23 patient's lung images. Results obtained establish the need for watermarking algorithms which show enhanced embedding as well as extraction performance for meeting the medical image indexation requirements.*

Keywords: *Lung CT image, visible watermarking, invisible watermarking, watermark embedding, watermark extraction.*

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1. Introduction

Watermarking is used in various contexts depending upon their needs. There are different types of watermarking like digital image watermarking, video watermarking, audio watermarking, digital signal watermarking and text watermarking. Initially, watermarking was used to provide security especially in military applications. The signal or message sent by the sender is invisibly watermarked. The receiver has to extract the watermark and the original message separately to verify whether he has received flawless message by the correct person. Image, video and audio watermarking was used particularly to provide copyrights.

Digital image watermarking helps to embed the watermark into the host image. The host image is the original image over which watermarking algorithms are applied. The watermark can be an image or a text which has to be embedded into the host image. Watermark embedding or simply watermarking is the process of applying watermarking algorithms so as to embed the watermark image into the host image to get a watermarked image. Watermark extraction or simply extraction is the process of retrieving the embedded watermark from the watermarked image. Extraction is possible only when the watermarking process is reversible. If the watermark embedded is irreversible, then extraction of the embedded watermark is impossible.

Depending on the requirement, the process of watermarking can be chosen as reversible or irreversible. When watermarking is done to provide copyrights or to solve ownership issues, irreversible method of watermarking is chosen. When one needs to provide authentication, watermarking becomes reversible. Other needs for watermarking are to provide reliability, confidentiality and security. Xuehua [22] has classified watermarking process based on various parameters.

Based on its characteristic property, watermarking is called robust or fragile. When watermarking is done depending upon its purpose, then it can be classified as copyright protection watermarking, tampering tip watermarking, note anti-counterfeiting watermarking and anonymous mark watermarking. If the watermark is visible, then it is called visual watermarking and when it is invisible, watermarking is called blind watermarking. It is also classified based on the attaching media-image, video, audio, text.

In medical domain, large databases containing varieties of images of different persons require safe and secured storage. While indexing these databases with relevant data, the storage bandwidth reduces and the retrieval becomes easier. The main goal of watermarking the medical images is to provide integrity and to index them properly. When we watermark them using reversible technique and index them based on the patient's details, it will be easy when retrieving them at latter stages. In this paper, we discuss about the existing algorithms for watermarking.

The Discrete Cosine Transform (DCT) based visible watermarking technique is discussed [4]. Visible watermarking is used to provide copyrights to the images. Additionally three invisible techniques are discussed and their applications, limitations are discussed. Finally a comparison of all four methods is presented.

2. Related Work

For embedding watermark into the host image, watermarking algorithms are used. Xuehua divide the watermarking algorithms into two broad categories [22]. One category is spatial domain based algorithms which include Last Significant Bit (LSB) algorithm, patchwork algorithm and texture mapping coding method based watermarking algorithms. Another category of watermarking algorithm is transform domain based digital watermarking algorithms.

Several reversible techniques like reversible algorithm utilizing the gray scale value and the correlation value [11], reversible watermarking algorithm using the knowledge digest information for watermarking [3], reversible data hiding algorithm [16] using random diffusion and accurate prediction [8], using local maximum amplitude wavelet coefficient quantization [4] have been designed such that the original host image and the watermark image could be retrieved after extraction process.

Tiwari *et al*. [15] embedded the watermark into the host image using Data Encryption Standard (DES) algorithm. It follows symmetric key cryptography technique. Initially the original image is applied for Discrete Wavelet Transform (DWT) before further processing. The watermark image and the original image are divided into blocks of same size. Then all the blocks are appended to get the complete encrypted image.

Wakatani [19] and Lestriandoko and Nuryani [7] suggested a watermarking method which is based on the image's Region of Interest (ROI). ROI is used as image digest. It is an irreversible method which produces the watermarked image by embedding the payload to difference of last bit from the Non-ROI region of the image. Since we cannot extract the original image from the watermarked image, it can be used only for authentication [12]. Although it shows good Peak Signal to Noise Ratio (PSNR) value, it requires enhancement in strength and image quality.

Verma and Tapaswi [17] proposed a Noise Sensitive Region Based Watermark Embedding (NSRBWE) technique. This method uses bit plane alteration scheme for watermark embedding. It also provides security with the help of a secret key, κ. When a robust, transparent, reversible and secured watermark is needed, this method can be employed. The original image can be constructed by eliminating the watermark image only with the help of the secret key. Watermark can be removed only when the other end knows the secret key. Algorithms also use cryptographic techniques in order to provide integrity and authentication for the medical images [5].

A joint fingerprint/encryption/dual watermarking system was developed by Viswanathan and Krishna [18] to address the issues in teleradiography. Fingerprint verification was done using invariants and encryption with the help of a secret key to be used with the stream cipher algorithm. While dual watermarking was carried out using spatial fusion. The proposed system has shown good results with DICOM images. Bouslimi *et al*. [2] has combined the substitutive watermarking algorithm (for watermarking) and the stream cipher algorithm or block cipher algorithm (for encryption) in order to verify the reliability for medical images.

Coatrieux *et al*. [3] and Lim *et al*. [9] proposed watermarking procedure for medical images. The medical image authenticity and security can be achieved by two modes of watermarking operations. In first mode, the watermark is embedded into host image and later. In second mode, the watermark is extracted from unaltered components of the image.

Singh *et al*. [13] used Wavelet Transform Domain (WTD) to watermark medical images by utilizing selective DWT coefficients. Sukanesh and Karthikeyan [14] proposed a methodology in which medical images stored in a cloud-based medical enterprise archive are watermarked. The data is hided in integer lifting transform domain of the medical images.

In this paper we take watermarking algorithms in different context in order to experiment with medical images, especially lung CT images. Algorithms from cosine transform domain, wavelet transform domain, using pattern operators and singular value decomposition were taken and experimented. Both visible and invisible techniques were chosen.

3. Methodology

Watermarking of medical images involve immense care during embedding and extracting of watermarks to/from the host image. Medical databases having huge volumes of patient's records require adequate maintenance so as to handle them efficiently. Watermarking can be used for indexing the medical records with respect to the patients. Existing algorithms provide efficient methods for watermarking. Here, four existing algorithms were applied over the lung CT images.

One visible watermarking technique based on DWT is applied to get a watermarked CT image which has the watermark visible to the viewers. Three other algorithms are invisible watermarking techniques. They are

1. Local Binary Pattern (LBP) based watermarking.
2. Integer Wavelet Transform (IWT) based watermarking.
3. Watermarking using Redundant Discrete Wavelet Transform and Singular Value Decomposition (RDWT-SVD).

Watermark embedding is the process of embedding or inserting the message or content into the original or

host image. The host image chosen is the lung CT images. Generally, the message embedded is the Electronic Patient Record (EPR) or the logo. Here, we have chosen the watermark image as the logo image.

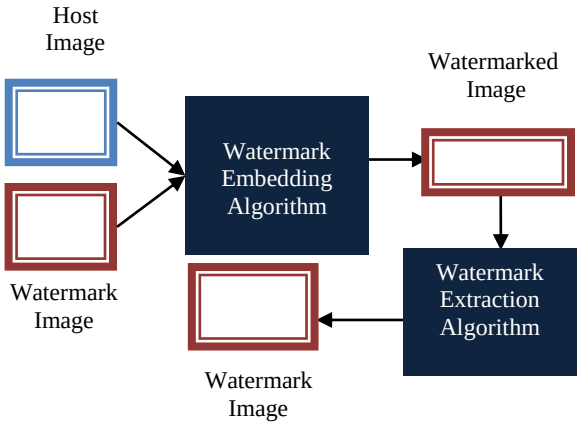


Figure 1. General watermarking process.

Embedding should be done in such a way that it satisfies all the properties like security, confidentiality, reliability, availability, integrity, authenticity, traceability and should ensure legitimacy. Watermark extraction is the process of getting the message back from the watermarked image. Generally, it is the reverse process of embedding. Watermark detection algorithm is applied over the result of embedding process to get the original host image and the watermark message separately. The algorithm used to extract the watermark from the watermarked image should be robust. The general process of digital watermarking is shown in Figure 1.

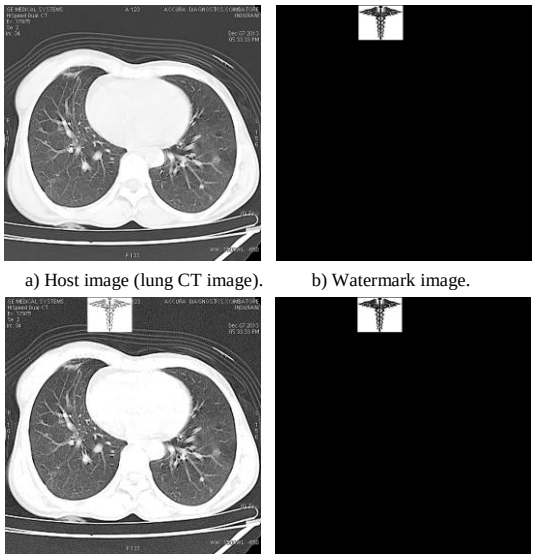
3.1. Discrete Cosine Transform (DCT) Based Watermarking

Watermarking is done using various domains. DCT is used to develop a visible watermarking technique [10]. The DCT represents an image as a sum of sinusoids of varying magnitudes and frequencies. When DCT is taken, almost the entire image's information gets concentrated over few coefficients of the DCT. Thus reducing the energy required. This satisfies the compactness property. The host image is initially processed to get the DCT coefficients. With a suitable embedding factor, host image's DCT coefficients are modified with the watermark's DCT coefficients. After transforming the domain values, inverse cosine transform is computed to get a visible watermarked image.

Since lung CT images are chosen, the watermark is selected in such a way that it does not affect the important portion of the medical image. The algorithms for embedding and extraction of watermark are defined in Algorithms 1 and 2. The host image, watermark image used as the input for this algorithm is given in Figures 2-a and 2-b. After applying watermark embedding algorithm based on DCT Algorithm 1, the resultant watermarked image is shown in Figure 2-c. The extracted watermark using Algorithm 2 is shown in Figure 2-d.

Algorithm 1: DCT based watermark embedding algorithm

Input: Host image and watermark image.
Output: Watermark embedded image.
begin
read the host image, H and the watermark image, W
resize H and W such that both becomes same size
extract the DCT coefficients of H and W
select a suitable embedding factor, α for visible watermarking
$H^W_{i,j} = H_{i,j} + (\alpha * W_{i,j})$, *where i and j are number of rows and columns of the images*
apply inverse discrete cosine transform to get the watermarked image
end



a) Host image (lung CT image). b) Watermark image.
c) Watermarked image. d) Extracted watermark.

Figure 2. DCT based watermark embedding and extraction.

Algorithm 2: DCT based watermark extraction algorithm

Input: Watermark embedded image.
Output: Extracted watermark image.
begin
read the watermarked image, HW and the host image,H
find the DCT coefficients of HW and H
apply the following formula to both the images
$W_{i,j} = (H^W_{i,j} - H_{i,j}) / \alpha$, *where I is the number of rows and j is the number of columns*
apply inverse discrete cosine transform to extract the watermark image from the watermarked image and the host image.
end

3.2. Integer Wavelet Transform (IWT) Based Watermarking

Watermarking can be done using wavelet domain and can be made invisible. IWT eliminates the limitations of watermarking algorithm based on LSB and Most Significant Bit (MSB). The redundancy caused by LSB and MSB based algorithms can be easily

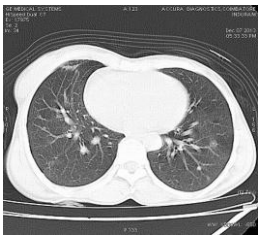
eliminated using the IWT based method. Since IWT is based on integer to integer calculations, there is no possibility of round-off errors thus eliminating redundancy. The watermark is embedded using bit-plane embedding in IWT domain [21]. If we use higher bit plane, then we will have higher bias. Choosing very low bit planes result in degradation of image's quality. Thus middle bit-plane is chosen in IWT domain so as to maintain the watermarked image same as host image. Further to prevent watermarked image have PSNR, sub bands used is high frequency sub bands. The algorithm for embedding and extraction is given below (refer Algorithms 3 and 4 respectively). The input and output of the algorithms is shown in Figure 3.

Algorithm 3: IWT based watermark embedding algorithm.

Input: Host image and Watermark image.
Output: watermarked image.
begin
read the image and convert it to gray scale
decompose the image using IWT
using the 5th bit, choose the sub bands
compress data in 5th bit using arithmetic coding
insert the compressed data and the watermark image into the host image.
compute inverse integer wavelet transform to get the watermarked image
end

a) Host image (lung CT image).

b) Watermark image.



c) Watermarked image.

d) Extracted watermark.

Figure 3. IWT based watermark embedding and extraction.

Algorithm 4: IWT based watermark extraction algorithm.

Input: Watermarked image.
Output: Extracted watermark image.
begin
read the watermarked image and decompose it using IWT
extract the embedded symbol from the 5th bit
extract the embedded data to get the original bit sequence
construct the sequence and decode to get original watermark image
take inverse integer wavelet transform to get the original host image
end

3.3. Watermarking Based on Redundant Wavelet Transform and Singular Value Decomposition (RDWT-SVD)

DWT is one of the most commonly used watermarking algorithms. Most important limitation of DWT is the shift variance. Since it does not support shift invariance property, the extraction of watermark image and the host image from the watermarked image becomes difficult. This drawback can be solved using the RDWT-SVD based watermarking algorithm [6]. SVD that helps to detect the intrinsic algebraic properties of images. The brightness of the image is represented using the singular values and reflect geometric properties are represented using the singular vectors. Variations in singular values do not affect the watermark deeply. Hence, SVD greatly helps in providing robust watermarking technique.

Algorithm 5: Watermark embedding based on RDWT-SVD algorithm.

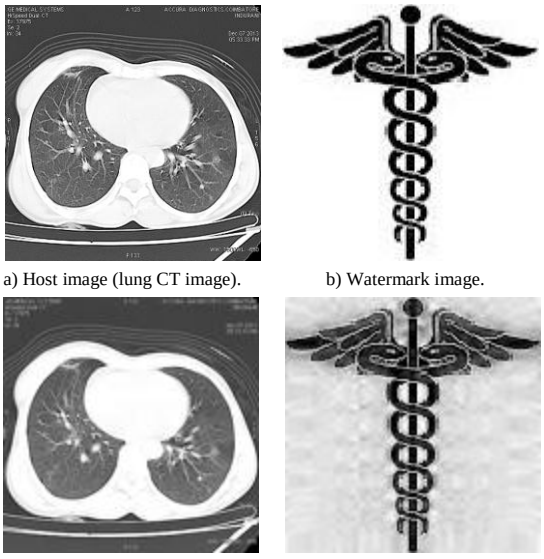
Input: Host image and watermark image.
Output: Watermark embedded image.
begin
apply redundant DWT to the host and watermark image.
apply SVD to the low frequency sub band extracted from the result of RDWT.
modify singular values using the following formula: $S^* = S^l + \alpha S$, *where α is the scaling factor.*
apply inverse SVD followed by inverse RDWT to the transferred image in order to obtain watermarked image.
end

The embedding and extraction process of RWDT-SVD based watermarking is presented in Algorithm 5 and algorithm 6. Initially, both the host image and the watermark image are applied DWT redundantly and SVD successively. Then, the singular values of the host image are modified with the singular values of the watermark image. Finally, inverse SVD and RDWT are applied to get the watermark embedded image. This process yields an invisible watermarked image. To extract the watermark image, the same process is repeated in reverse manner. The first step is to apply RDWT and SVD to the watermarked image. Then, the singular values of the host image and the watermarked image are extracted. Finally, inverse process is applied to get the initial watermark image. The input and output of the algorithms is shown in Figure 4.

Algorithm 6: Watermark extraction based on RDWT-SVD algorithm

Input: Watermark embedded image.
Output: Extracted watermark image.
begin
apply redundant DWT to the host and watermark image and decompose it.
apply SVD to the low frequency sub band extracted from the result of RDWT.

modify singular values using the following formula:
$S^w = (S^* - S^l)/\alpha$, where α is the scaling factor.
apply inverse SVD followed by inverse RDWT to the transferred image to extract the watermark image.
End



a) Host image (lung CT image). b) Watermark image.
c) Watermarked image. d) Extracted watermark.

Figure 4. RDWT-SVD based watermark embedding and extraction.

3.4. Local Binary Pattern (LBP) Based Watermarking

LBP operator is generally used for classification. It is considered as one of the feature for texture classification. It is also used in measuring the local contrast within pixel's neighborhood [20]. For watermark embedding and extraction, LBP operator makes use of local pixel contrast. The LBP operator is defined in a circular local neighborhood. Using the center pixel as the threshold, its circularly symmetric P neighbors within a certain radii R are individually labeled as 1 when the value is larger than the center, or labeled as 0 when the value is smaller than the center. LBP in the neighborhood is defined as Equation (1).

$$LBP_{P,R} = \sum_{0}^{P-1} S(g_p - g_c) \times 2^P \quad (1)$$

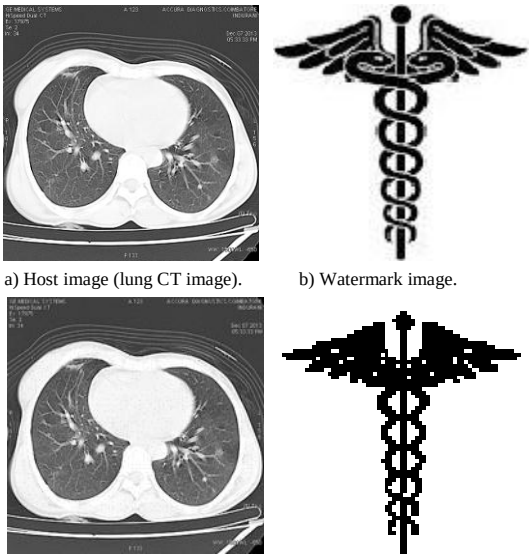
Where g_p and g_c is the gray level value of neighborhood and center pixel respectively. $S(x)$ is a function which is defined as Equation (2).

$$S(x) = \begin{cases} 1, if\ x \geq 0 \\ 0, otherwise \end{cases} \quad (2)$$

When embed the watermarks by changing the value of $f(S_p)$ in a local region is defined as Equation (3).

$$f(S_p) = Bool(1(S_p) - 0(S_p) > N) \quad where\ N \leq p - 1 \quad (3)$$

The detailed procedure for watermark embedding and extraction is given in Algorithms 7 and 8. These algorithms were applied over the images in Figures 5-a and 5-b. The watermarked image using LBP operator is obtained as shown in Figure 5-c. The embedded watermark is extracted using the extraction Algorithm 8 and it is as shown in Figure 5-d.



a) Host image (lung CT image). b) Watermark image.
c) Watermarked image. d) Extracted watermark.

Figure 5. LBP based watermark embedding and extraction.

Algorithm 7: LBP based watermarking embedding

Input: Host image and watermark image.
Output: Watermark embedded image.
begin
read the host image and the watermark image.
divide the host image into a fixed number of non-overlapping region blocks.
calculate f(Sp) using LBP pattern
if f(Sp) is equal to the watermark bit,
keep neighborhood pixels unmodified
else
modify any neighborhood pixel in order to make it consistent with the watermark pixel
end

Algorithm 8: LBP based watermark extraction

Input: Watermark embedded image.
Output: Extracted watermark image.
begin
read the watermarked image
calculate $f(S_p)$ from the watermarked image.
define watermark pixel with respect to $f(S_p)$
if $f(S_p) = 1$, watermark pixel, w=1
else watermark pixel, w=0
end

4. Results and Discussion

The dataset consists of 1278 lung CT images collected from 23 patients. The patients were from different age groups with the minimum of 24 years to the maximum of 75 years. The number of scans for a patient is not constant. It varies according to the type of screening. Table 1 shows the number of images from different patients.

Table 1. Patient's ID and their corresponding number of images.

Patient ID	Image Count	Patient ID	Image Count
P1	97	P13	18
P2	194	P14	6
P3	21	P15	12
P4	44	P16	10
P5	25	P17	25
P6	167	P18	11
P7	51	P19	25
P8	25	P20	96
P9	13	P21	68
P10	160	P22	15
P11	14	P23	168
P12	13	**Total No. of images**	**1278**

The samples of scan images and the results after applying watermarking algorithms to the lung CT images can be referred to Figures 2 to 5. Both visible and invisible watermarking algorithms were applied to the images. Patient wise evaluation is done.

Table 2. PSNR(dB) of four algorithms.

Patients ID	DCT Based Watermark Embedding	LBP Based Watermark Embedding	IWT Based Watermark Embedding	RDWT – SVD Based Watermark Embedding
P1	31.38	41.84	33.40	37.71
P2	32.06	40.86	29.42	37.77
P3	33.31	38.96	29.69	42.58
P4	32.39	39.49	29.41	33.89
P5	33.43	38.65	29.68	40.75
P6	32.09	39.78	29.33	34.08
P7	32.22	41.41	29.73	40.11
P8	32.26	39.92	29.99	39.59
P9	32.94	38.81	29.19	34.26
P10	31.72	39.54	29.63	34.25
P11	31.74	41.24	29.69	39.72
P12	31.37	40.96	29.67	38.85
P13	32.49	39.96	29.58	40.18
P14	33.37	38.64	29.18	34.33
P15	31.76	39.99	29.54	34.23
P16	32.28	39.65	29.44	34.06
P17	32.78	40.28	29.78	41.59
P18	32.35	39.97	29.43	34.48
P19	32.82	39.17	29.24	35.38
P20	30.98	39.64	29.24	34.82
P21	33.61	37.52	28.94	33.43
P22	32.53	39.66	30.09	34.04
P23	32.08	39.43	29.14	33.99

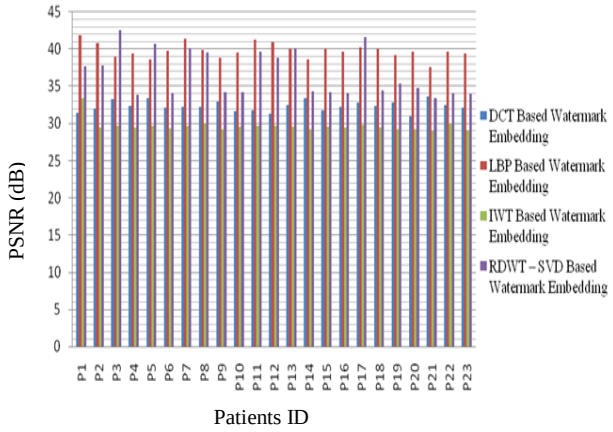


Figure 6. PSNR (dB) of four algorithms.

Correlation Co-efficient (CC) is calculated between the watermark image and the extracted watermark image. Its value will be between 0 and 1. When the value is nearer to 1, then the watermark extraction algorithm is very efficient in extracting the watermark from the watermarked image. Table 2 shows the evaluation results of watermark embedding from all four algorithms and Figure 6 shows the graph of PSNR of four algorithms.

CC helps to compare the original watermark image and the extracted image from the watermark extraction algorithm. A perfect extraction algorithm gives a value of 1 for CC. Table 3 shows the watermark extraction results of all the patients and Figure 7 shows the graph of CC of four algorithms. DCT based watermark extraction algorithm shows better extraction of watermark from the embedded image. While comparing invisible techniques, IWT based watermark extraction provides better extraction of watermark image. The average CC value of IWT based extraction is 0.99.

Table 3. CC of four algorithms.

Patients ID	DCT Based Watermark Extraction	LBP Based Watermark Extraction	IWT Based Watermark Extraction	RDWT – SVD Based Watermark Extraction
P1	1	0.6841	0.9948	0.2988
P2	1	0.7667	0.9919	0.2881
P3	1	0.9885	0.9853	0.9856
P4	1	0.8484	0.9919	0.9916
P5	1	0.9986	0.9919	0.9059
P6	1	0.8750	0.9934	0.9274
P7	1	0.8128	0.9919	0.9684
P8	1	0.8124	0.9948	0.0511
P9	1	1.0000	0.9919	0.9684
P10	1	0.8251	0.9948	0.8646
P11	1	0.6229	0.9919	0.0167
P12	1	0.8547	0.9919	0.0482
P13	1	0.9162	0.9919	0.9914
P14	1	0.9839	0.9919	0.9706
P15	1	0.7921	0.9919	0.9844
P16	1	0.8673	0.9919	0.9902
P17	1	0.8983	0.9919	0.9903
P18	1	0.9797	0.9919	0.9686
P19	1	1.0000	0.9919	0.9167
P20	1	0.7524	0.9928	0.9132
P21	1	0.9999	0.9919	0.9919
P22	1	0.9804	0.9919	0.9896
P23	1	0.9060	0.9928	0.9389

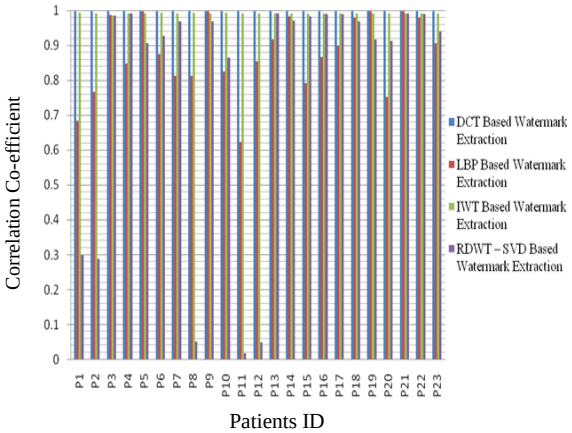


Figure 7. CC of four algorithms.

The RDWT-SVD based and LBP based watermark extraction algorithms shows 0.87 and 0.80 as their CC

respectively. The IWT based watermark embedding algorithm retains much information in the watermarked image. This resulted in lower PSNR value compared to other techniques. While extracting the watermark image, IWT based extraction algorithm uses the restored information from the watermarked image thus giving better CC compared to other invisible watermarking techniques. For indexing purpose, LBP based embedding helps to better preserve the information of the host image. While extracting the watermark image, IWT based method provides better performance.

5. Conclusions and Future Work

This paper discusses the implementation of invisible and visible watermarking methods for indexing purposes. For embedding purposes, LBP shows better performance however, for extraction purposes, IWT shows better performance where LBP shows the least. Therefore, for indexing medical images, we need an algorithm which shows better performance in both embedding and extraction. The hybrid method should be able to index the images efficiently in the database. This paper involves the embedding of copyright image as watermark. Instead using the patient information along with the copyright image would result in improved clarity of indexing medical images.

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