How to Cite:
Rajakumari J, J., & Murugeswari G, M. G. (2022). An efficient watermarking technique using contourlet transform for medical images. *International Journal of Health Sciences*, *6*(S7), 5295-5311. https://doi.org/10.53730/ijhs.v6nS7.13117

An efficient watermarking technique using contourlet transform for medical images

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***Abstract*---**The purpose of digital image watermarking is to hide secret information, objects, or logos on some multimedia content to secure the information or attack. Unauthorized individuals may attempt to access data or images during data transmission for illicit purposes. By establishing a hospital logo or Electronic Health Record (EHR) into a source images, medical image watermarking secures the data contained in medical images. In this paper, we present a brand-new watermarking scheme for medical images using contourlet transform. Each subband's energy value is calculated, and the middle energy subband is taken into account for the embedding process. Four different types of digital image watermarking techniques are used to compare the performance of the proposed watermarking scheme. (I)DWT without Band selection (II) DWT - SVD (IIII) DWT with Bandselection (IV) Curvelet Transform Peak Signal to Noise Ratio (PSNR), a performance metric, shows that the proposed method produces 52.63 percent of PSNR value for CT images and 53.98 percent of PSNR value for MRI images. When compared to other watermarking techniques, the contourlet transform provides better results, as evidenced by the Peak Signal to Noise Ratio.

***Keywords*---** Image,Embedding,DataHiding,ContourletTransform.

Introduction

Security is a crucial consideration when digital images are transmitted through a communication channel due to the explosive growth of multimedia content. While transmitting digital images through a communication channel, certain

International Journal of Health Sciences ISSN 2550-6978 E-ISSN 2550-696X © 2022.
Manuscript submitted: 9 May 2022, Manuscript revised: 18 July 2022, Accepted for publication: 27 August 2022

techniques like steganography, watermarking, and cryptography are used for security purposes.

Securing patient information, such as Electronic Health Records (EHR), is a top priority in the medical industry as well. The vast majority of medical images used with hospitals are essentially kept in a database along with the patients' bio-signals and demographic text data. Unauthorized tampering, mismatching, and improper handling of data are a few issues with such data that is stored in massive databases. Additionally, effective and dependable transmission together with storage techniques is required for the exchange of bio signals, demographic texts, and medical images among both hospitals. Watermarking is currently a major research topic for improving the security of healthcare data. Digital watermarking is the process of incorporating data for authentication into a multimedia element, such as an image, audio, or video file. Typically, a watermark is embedded to provide information for copyright protection and to demonstrate the veracity of data. Increased image security, confidentiality, and integrity are achieved through the use of digital watermarking.

Watermarking algorithms concentrate on concealing them in order to protect the medical image. Information is anonymous and invisible thanks to watermarking, which is its main benefit. By obscuring the necessary information in the original image to announce rightful ownership, watermarking provides copyright protection to an image. For security reasons, the embedded data can be later extracted from or found in the multimedia image.

There are two different transform methods for watermarking. Spatial domain and frequency domain are them. The watermark data is inserted into the spatial domain as part of the spatial domain watermarking scheme. Least Significant Bit Modulation (LSB) is the most common algorithm used in the spatial domain. The original input image is processed using a modified Fourier transform in the Frequency domain watermarking scheme. DCT, DWT, and DFT are a few of the frequency domain watermarking schemes.

1. Literaturereview

In this section, the existing works for watermarking medical images are examined and presented.

Wavelet Packet Transform is used in the embedding process of a watermarking method created by Mothi.R et al. [20]. The embedding process is carried out in a specific wavelet sub-band after the original image has been split into several bands using the Wavelet Packet Transform. Sub bands are chosen based on energy levels and the data is embedded in the original image using the sub band with the lowest energy. The watermark is embedded into the low frequency sub-band of the A three-level DWT-based image watermarking method was created by Nikita Kashyap et al. [10]. Original image using the Alpha blending technique and a multilevel watermark bit is used for the embedding process.

Integer Wavelet Transform (IWT) & Singular Value Decomposition (SVD) were used to implement a watermarking scheme by Nasrin. Metal.[16] wherein the watermark data have been embedded into singular values of 1-level IWT decomposed subbands. For use in healthcare applications, Aditi Zeeretal [45] created a multiple watermarking system based on DWT-DCT-SVD. Using an extracted image watermark from a back propagation neural network (BPNN), the algorithm's robustness has been increased. Arnold Transform can be used during the embedding process to increase the security of watermark as well. A Biorthogonal Wavelet Transform Digital Image Watermarking was suggested by Rajendra Prasad et al. [35]. Biometrics as well as digital watermarking is used to protect this same copyright of digital images.

A watermarking technique based on DWT, DCT, and SVD methods was created by Md. Maklachur Rahman et al. [7] where the original image is rearranged using a zigzag sequence and the watermarking process is then applied to the rearranged image. A watermarking procedure based on a combination of DWT, DCT, and SVD methods was implemented by Navas K A et al. [8]. A DWT and DCT correlations contain watermark data that has been embedded using this method. A Particle Swarm Optimizer-based watermarking method was implemented in DWT and SVDdomain by Veysel Aslant as et al. [9].

A watermarking system was created in the multiple transform domain by Rajat Sharma et al. The original image is first divided into subbands using DWT, and all lower frequency sub-band then undergoes the Contourlet transform. With in contourlet transform, a detail sub-band can be used to embed watermark data, while a approximate sub-band is used to calculate optimised modification parameters. A watermarking model based on it's contourlet transform, created by SyC. Nguyen, KhaH., et al. [50], yields a PSNR value of 50. Four transforms were used to develop a watermarking method by Fares Kahlessenane et al. [51].They are (i) Discrete Wavelet Transform, (ii) Contourlet Transform , (iii) Discrete Shearlet Transform (iv) Discrete Cosine Transform. A medical image watermarking scheme developed by Sudeb Das et al. [52] uses a contourlet transform followed by a discrete cosine transform to produce a PSNR value of 41. In a watermarking scheme based on Discrete Wavelet Transform as well as Singular Value Decomposition technique, Ali Alzahrani et al. [53] divided a medical image into two regions, the ROI region and RONI region.

RONI region contains embedded watermark data. PSNR value offered by this scheme is 44.0567 db. A dual adaptive watermarking method using the Contourlet Transform was created for DICOM images by Farhad Rahimi et al. [54]. For use in E-healthcare applications, Puvvadi Aparna et al. [55] created a crypto-watermarking scheme. Three different types of patient data, including medical images, HER data, and face images, are used for the watermark data in this technique. All data is encrypted and transformed into bit streams. The bit sequences are then incorporated into the cover photo. Brain tumour automatic segmentation was carried out by Jayadevappa, D. et al. [57] using the Chan-Vese active contour model and the Contourlet transform. The Contourlet transform is employed in this work to collect edges and smooth contours in any direction.

Gunjal et al.[3] address some of the problems and difficulties associated with watermarking algorithms, including such Confidentiality, Reliability, Robustness, Imperceptibility, and Capacity or Payload. The author has identified various watermarking methods to address the problems and demands mentioned above.

In each proposed work, a watermarking process is carried out using the frequency domain method. Digital image watermarking schemes typically employ two techniques. They are frequency domain as well as spatial domain watermarking methods. Frequency domain watermarking techniques are much more successful in accomplishing a imperceptibility and robustness of the original image than spatial domain watermarking techniques. A proposed method compares the results of a Contourlet Transform watermarking method to the DWT with SVD, DWT without band selection, DWT to band selection, and a Curvelet Transform.

3. Methodology

Within that work, we offer a practical watermarking method that makes use of contourlet-transformed synthetic images. In general, the two-phase method is used to watermark medical image files. They are I incorporating the patient's electronic health record (EHR) into the medical image. EHR is removed from of the watermarking image (ii). Figures 1(a) and 1(b) show two phases of proposed watermarking scheme respectively. The process of the suggested watermarking scheme is described in the section that follows.

MedicalImageWatermarkingprocessusingContourletTransform:EmbeddingProcess

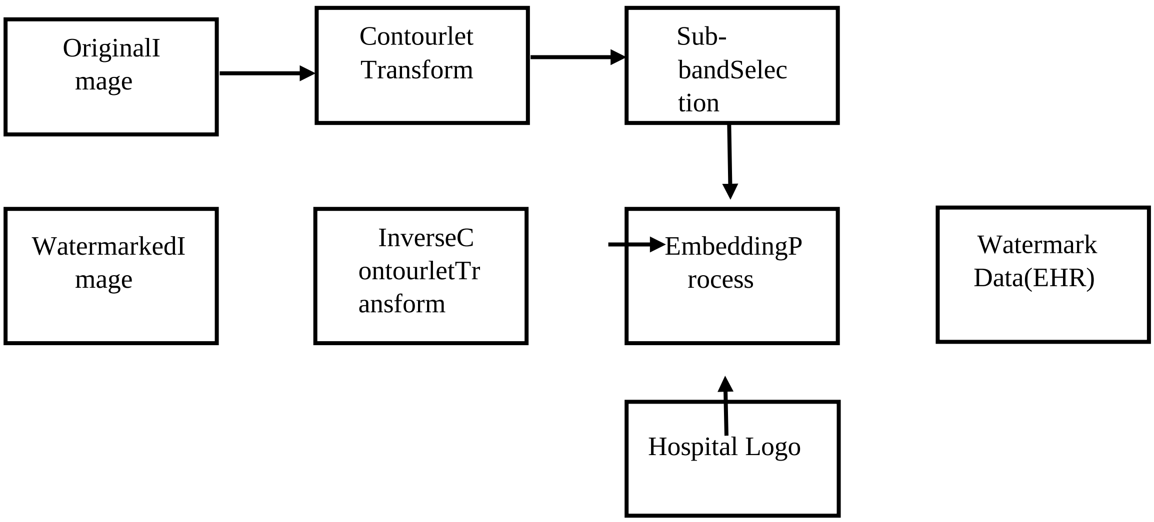


Fig1.(a)EmbeddingProcessusingContourletTransform

ExtractionProcess

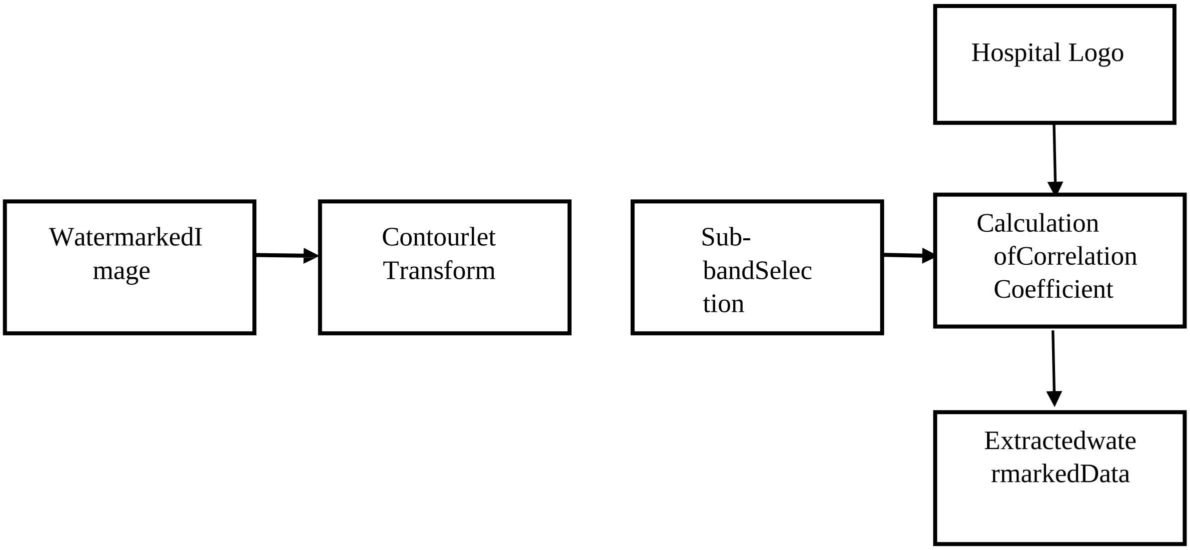


Fig1.(b) ExtractionProcessusingContourletTransform

a. Contourlet Transform

Contourlet Transform, which was found to be most effective transform for medical image analysis and deals with both smooth and sharp edges of such an image effectively, is being used in the watermarking process. Do and Vetterli created the first iteration of a contourlet transform, a two-dimensional transform technique for image representations, in 2002. A Contourlet Transform has utilised two filter bank structures. Laplacian Pyramid (LP) filter and Directional filter bank are them (DFB). Point discontinuities are found using Laplacian filter, but they are joined into linear structures using the Directional Filter Bank.

Low frequency components will all leak into directional sub bands of a directional filter, that is only suitable for high frequency components. This is the rationale behind combining a Directional and Pyramidal filters. All of the low frequency sub bands will be completely eradicated by this multiscale resolution combination. In order to acquire band pass signals and to obtain directional information of an image, image signals are permitted to pass through directional filter as well as the pyramidal filter-subbands. Pyramid Directional Filter Bank (PDFB) structure is another name for this double filter bank agreement. The fact that this contourlet transform clearly reconstructs original image is a crucial characteristic. Smooth edges of images with various elongated shapes in a variety of directions can be captured by contourlet transform.

b. Band Selection

A two-level decomposition process is used to break down a medical image with in proposed contourlet technique-based watermarking scheme. So when contourlet transform is used, a image is initially decomposed into 4 subbands. A last three sub bands have been known as directional filters, while the first sub band is known as the Laplacian Pyramid sub band. First subband is further divided into four subbands at the second level of decomposition. The appropriate band is then chosen to encoded the data for band selection process.Energyvalue of each sub bands iscalculatedusingEquation (1).

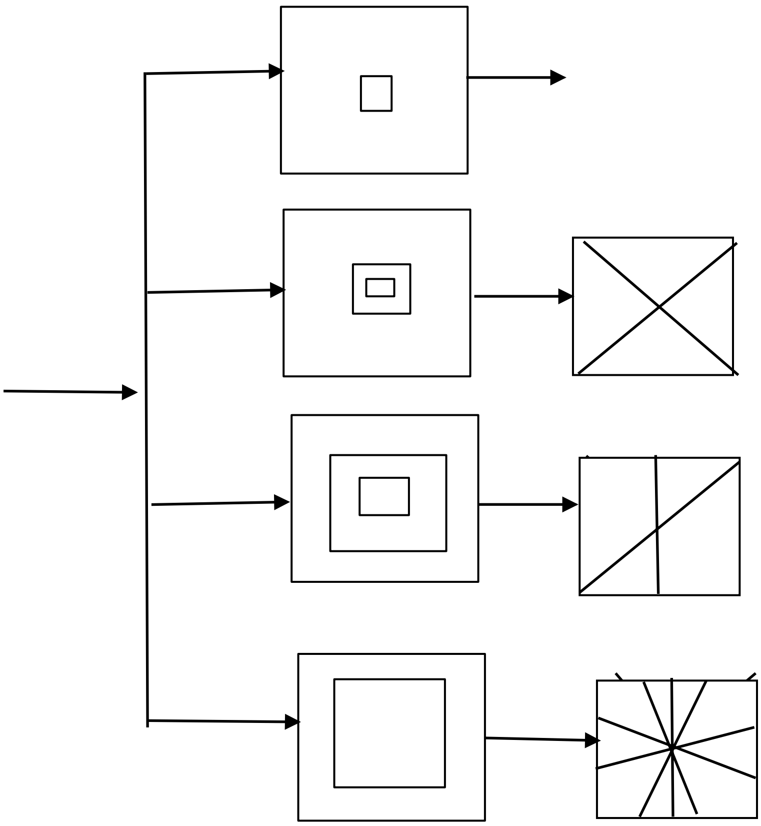
$$\text{Energy of each sub band} = \frac{sum of square of each pixel in the band}{total number of pixels in the band}$$

(1) Each sub band's calculated energy values will be listed in ascending order. For embedding process, the subband with middle energy value will be taken into account. H ospital logo is being used as the reference image in this process, and electronic health record (EHR) will serve as watermark information. Data like the patient's name, age, sex, blood type, weight, hospital name, doctor name, etc. are all contained in the EHR. Binary 0s and 1s are used to represent this watermark data. If the Watermark bit is set to "0," the middle energy subband will be used for the watermarking process (2). If the watermark bit is set to "1," the equation will be used to perform the embedding process (3).

EmbeddingData= +(0.9*Hospitallogo){ifwatermark=0} (2)

EmbeddingData= -(0.9*Hospitallogo) {ifwatermark=1} (3)

0.9istheembeddingfactorwhichprovidesabetterresultsforembeddingdatacompared toother values such as 0.2,0.3,0.4 etc.,



Low-passsubband

Band-passdirectionalsubbands

OriginalImage

Fig2.Band Selection in Contourlet Transform

a. EmbeddingProcessusingContourletTransform:

i. The original image is transformed using the Contourlet algorithm. It offers 4 subbands, including DF (Directional Filter) subbands and LP (Laplacian Pyramidal) subbands. Four sub bands are once more applied to the LP sub band.

ii. Watermarkdata(EHR)isconvertedintobinaryvaluesof‘0’sand‘1’s.Embedding factor(α)is taken as 0.9.

iii. Calculate each subband's energy value. Energy values should be sorted ascending. In comparison to Lower and Higher energy values, Middle energy value yields better embedding results. In order to consider the middle energy value among the sorted energy values.

In selected middle energy sub band, the watermark data (EHR) is embedded.InverseContourletTransformis applied forobtaining thewatermarked image.

b. ExtractionProcess

i. Inthisextractionprocess,thewatermarkimageissubjectedintoaContourletTransform.Middle energyvalue ofeachsub bandis calculated.

ii.

iii. Correlationcoefficientiscalculatedbetweenthemiddleenergysubbandvalueandthe hospital logo (reference image) is shown in eqn(4). If this value is greater than‘0’,thenextracted watermarkbit will be‘0’otherwiseitwill be‘1’.

$$CorrelationCoefficient=\sum_{i=0,=0}^{i=m,j=n}(Subband*ReferenceImage) \quad (4)$$

Peak Signal to Noise Ratio (PSNR) is calculated by considering the original imageandembeddedimagetoevaluatetheperformanceofproposedscheme.Thenthe Embeddedimagecan be transmitted through the Internet in Hospital Management applications to secured thepatientdata.

4. Experimental results and performance analysis

4.1. Dataset

Medical professionals use medical imaging, also known as radiology, to take pictures of different body parts in order to diagnose or treat patients. Medical images are used to examine the patient's body parts and tissues in order to diagnose any diseases that may be present. A strong magnetic field and radio waves are used in magnetic resonance imaging (MRI) to create incredibly clear images of the body's organs and internal structures. Cross-sectional images are produced by computed tomography (CT), which combines X-ray images taken from various angles.

In this study, we used a few databases of free MRI and CT image collections for experimental purposes. The list of databases used in this work arelisted inTable 1.

Table1.Data setsofMRI and CT MedicalImages

SL.NO	DATABASES	WEBSITES
1	**MRI Images**Brain MRIKneeMRI FetalMRI	https://www.kaggle.com/navoneel/brain-mri-images-for-brain-tumor-detectionhttps://stanfordmlgroup.github.io/competitions/mrnet/ https://f1000research.com/articles/6-93

2	**CT Images**Lung CTBrainCT	https://wiki.cancerimagingarchive.net/display/Public/4D - Lunghttps://wiki.cancerimagingarchive.net/display/Public/Brain-Tumor-Progression

4.2. **ElectronicHealthRecord(EHR)**

The patient's name, age, date of birth, weight, and height are all included in electronic health record (EHR), including the hospital name as well as doctor's name. This EHR is incorporated into the original image during the embedding process, and this EHR data is extracted from embedded image during extraction phase.

PerformanceMetric: In order to evaluate the effectiveness of any algorithm in medical image processing, performance analysis is important and quantitative metrics are used. The metric employed in this work to evaluate the effectiveness of the suggested technique is PSNR.

PeakSignaltoNoiseRatio(PSNR)

Peaksignaltonoise ratioisusedtofinddifference betweenthe originalimage andprocessed image. The ratio between the maximum possible power of an image and the power ofcorrupting noise that affects the quality of an image is calculated.It is necessary to compare theidealclean imagewith Watermarked imageusingPSNR value.

$$\mathrm{PSNR} = 10 \log 10 \frac{\mathrm{Maximumvalue}}{\mathrm{MSE}} (5)$$

MSE = sum(sum(Original Image*Watermarked Image)) / (rows * columns)(6)

4.3. **ExperimentalResults**

Some of the sample MRI and CT images which are used for experimental purpose are shownin Fig 3.(a), (b) and (c) Fig 4.(a), (b), (c). shows the original medical image, Hospital Logo(Reference Image) andembedded image.

(a) Original Image (b)ReferenceImage (c)Embedded Image

Fig3.(a),(b),(c)ExperimentalResults ofWatermarkingprocessforMRIMedical Images

(a) OriginalImage (b)Reference Image (c)Embedded Image

Fig 4. (a), (b), (c)Experimental Results of Watermarking process for CT Medical Images

Inordertocalculatetheperformanceofproposedtechnique,theexperimentalresultsare comparedwithothertransformtechniquessuchasDWTwithSVD,DWTwithoutBandSelection,DWTwithBandSelectionandCurveletTransform.Table2andTable3showsthe PSNRvalues ofMRIandCTMedicalimagesfor DWT withSVD,DWTwithoutBandSelection,DWTwith Band selection,Curvelet Transform and ContourletTransform.

Table 2. Performance of Proposed Watermarking Scheme with Other techniques for MRIMedicalImages

SL.NO	MRI Image	DWT - SVD[18]	DWT withoutBS[21]	DWT with BS[56]	CurveletTransform[38]	ContourletTransform
1	MRI1	30.5204	28.6863	46.8023	36.1747	47.5753
2	MRI2	26.9814	21.5816	39.9389	33.5429	48.2219
3	MRI3	25.3076	23.4773	46.4842	58.8873	58.6240
4	MRI4	33.1564	26.6190	53.2025	40.6005	58.9197
5	MRI5	26.9814	21.5816	39.9389	33.5429	48.2219
6	MRI6	25.3076	23.5190	46.4842	12.8829	58.6240
7	MRI7	26.4482	23.3899	45.8987	11.9059	48.9343
8	MRI8	23.9684	20.0711	36.1992	30.2506	36.4160
9	MRI9	30.2125	24.8971	59.6454	31.4744	57.9273
10	MRI10	37.4595	28.5200	52.7468	55.5613	48.5827
11	MRI11	30.5204	28.6863	46.8023	36.1747	47.5753
12	MRI12	29.7687	23.7056	64.7392	41.0355	65.1729
13	MRI13	26.2207	22.5421	56.5042	36.8442	70.8302
14	MRI14	27.0308	22.2262	33.7922	12.7879	34.2033
15	MRI15	25.0729	23.1073	35.6197	29.8844	39.8504
16	MRI16	27.0608	22.7685	84.2544	28.6254	87.2647
17	MRI17	29.7687	23.7056	64.7392	19.1463	65.1729
18	MRI18	29.5281	24.8598	42.5919	58.8873	57.0694
19	MRI19	26.2207	22.5421	56.5042	31.4744	70.8302
20	MRI20	24.0603	25.2023	33.3953	28.0425	42.7599
21	MRI21	29.4154	20.8900	33.5964	21.8899	34.6167
22	MRI22	32.0387	26.3602	67.8199	58.8873	72.4935
23	MRI23	29.7407	24.7049	38.1515	41.0355	42.7504
24	MRI24	26.7608	24.1364	42.9904	44.0242	42.4608
25	MRI25	33.0954	24.5426	60.2946	31.4744	64.2816

AveragePSNR	**28.5058**	**24.0929**	**49.1654**	**34.6014**	**53.9752**

Table 3. Performance of proposed Watermarking Scheme with Other techniques forCTMedicalImages

SL.NO	**CT Image**	**DWT - SVD[18]**	**DWT withoutBS[21]**	**DWT withBS[56]**	**CurveletTransform[38]**	**ContourletTransform**
1	CT 1	28.2467	36.0264	48.5744	58.8873	55.0068
2	CT 2	32.0024	36.7000	48.1977	43.6013	54.1066
3	CT 3	29.9881	36.6811	49.1723	31.3316	51.9458
4	CT 4	29.2848	36.3885	48.3188	33.9525	44.4492
5	CT 5	31.1688	36.7405	48.3446	31.3806	45.8700
6	CT 6	31.2648	25.4606	44.4457	34.5353	43.7577
7	CT 7	29.0949	38.6950	50.1597	58.8873	54.7568
8	CT 8	28.0152	40.3631	54.7041	58.8873	55.6894
9	CT 9	27.4001	43.2260	51.4583	58.8873	54.0281
10	CT 10	28.1460	37.6626	49.4382	58.8873	54.3696
11	CT 11	26.8706	13.9458	51.7638	43.5598	57.2761
12	CT 12	28.6999	13.8674	51.7289	35.8670	52.6495
13	CT 13	29.2593	13.9183	45.3981	24.2991	50.8024
14	CT 14	30.3116	13.6591	52.0871	36.8989	53.2580
15	CT 15	28.9247	13.6798	52.3940	42.5735	52.5509
16	CT 16	29.4401	13.6587	51.7062	40.2265	52.5931
17	CT 17	29.6801	13.6837	51.7533	42.4481	52.2835
18	CT 18	30.3568	13.7639	51.7601	36.7635	51.6161
19	CT 19	30.8719	13.7687	50.9575	39.9279	52.7482
20	CT 20	30.6864	13.7696	52.3446	35.3989	52.8874
21	CT 21	30.6252	13.8006	52.3008	34.9519	52.9053
22	CT 22	30.0827	13.8727	52.5643	38.2248	53.5549
23	CT 23	30.0978	13.8095	53.6844	44.5848	54.1461
24	CT 24	27.7387	14.3780	42.7870	16.0730	48.2988
25	CT 25	29.4396	13.6498	52.0143	43.9138	53.2626
AveragePSNR		**29.5534**	**23.5935**	**50.5743**	**41.9720**	**52.6396**

Discussion

The performance of the proposed watermarking scheme is compared with few watermarkingtechniques namely DWT with SVD, DWT without Band Selection and DWT with Band Selectionand Curvelet Transform. The experiment was performed both CT and MRI images. ContourletTransformbasedwatermarkingschemeformedicalimageistestedandpresentedinTable2and

Table 3. From the above table PSNR calculation for various medical images were experimentedand noted.From the dataset, totally 25 samples of both CT and MRI images are taken for theexperiment. For MRI medical images, DWT with SVD gives PSNR value of 28.5058 and DWTwithout Band Selection gives PSNR value of 24.0929 and DWT with Band Selection gives PSNRvalue of 49.1654 Curvelet Transform gives PSNR value of 34.6014 and Contourlet Transformprovides PSNR value of 53.9752. For CT medical images DWT with SVD gives PSNR value of29.5534 and DWT without Band Selection gives PSNR value of 23.5935 and DWT with BandSelection gives PSNR value of 50.5743and Curvelet Transform gives PSNR value of 41.9720and Contourlet Transform gives PSNR value of 52.6396. The values of DWT with SVD, DWTwithout Band Selection, DWT with Band Selection, and Contourlet Transform of every sample ofCT and MRI images are noted and the average is calculated. From the above average PSNRcalculations of MRI and CT images, Contourlet Transform provides better PSNR value comparedwith other Watermarking Techniques. Since medical images are having curve shaped components,the Contourlet Transform preserves them. Because of this reason, it is found that the performanceof the proposed scheme working better.The selection of middle energy value also helps toimprovethe performanceof proposed scheme.

Conclusion

This study suggests a watermarking method for medical images using the contourlet transform and a middle energy band selection. Additionally, this work assesses an effectiveness of the proposed scheme with a few already-in-use watermarking techniques using Discrete Wavelet Transform (DWT) with band selection, DWT without band selection, and DWT with Singular Value Decomposition (SVD). Different medical images, including MRI and CT images, are taken into account for experiment. Peak Signal to Noise Ratio (PSNR), which is used as a performance measure for contrast. The proposed scheme generates PSNR values of 52.63 percent and 53.98 percent for CT and MRI images, respectively. An experimental finding showed that Contourlet Transform outperforms other content protection techniques.

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