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Research paper

Reversible image watermarking technique using LCWT and DGT

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Abstract

In this contemporary world procuring our confidential data against some unknown person is very significant. Thus to have a high reliability of data security watermarking technique is applied before transmitting the data. This proposed work LCWT and DGT decomposition gives an effective technique to protect hypertensive related information based on reversible watermarking. LCWT has the superiority of multi-resolution fundamental analysis of wavelet transform and reflects representation of image domain in LCT. And using DGT decomposition the patient information has to embed inside high frequency subband wavelet and the watermarked information will be extracted by the receiver without any loss, to reconstruct the original image information. The reliability of the proposed method is analyzed by comparing the experimental results of similarity index, normalization and peak signal to noise ratio.

Keywords: *DGT; LCWT; PSNR; Normalization; Watermarking*

1. Introduction

Digital Watermarking plays a vital role to secure the image or data before transmitting for external use. In this present digital world data security is very important in all aspects of area to transmit the data. Thus medical institutions become fully digitized with high security to send the patient information for future process. Watermarking is done by inserting an additional information into a cover image and ensures data protection i.e, copyright or data authentication. The information in watermarked image are invisible and undeterminable. At the receiver side the inverse methodology is applied in order to recover the information embedded in that host image without any degradation. But many demand for identification of suitable properties has to be done in order to create a new algorithm for digital image watermarking. Properties like robustness, capacity, security and degradation should be taken as major parameters to reconstruct the original image from watermarked image[1].

Wavelet Transform is one of the best image compression method for lossless image processing. The ultimate goal of image compression is to insert the data in a little area as much as possible. By wavelet transform image compression can be extended in various transients like sound, video and 2D images. Widespread discrete cosine transform enhance the transient data to convert into smaller information in some other form. And the linear canonical transforms is the abstraction of Fourier Transform, properties like scaling, cascading, phase & shift modulation, shearing and rotation are taken into consideration. In the proposed method transformation in time frequency, phase space coordinates and position momentum are incontestable.

Le and Aburdene introduced the functions of edge detection in digital image processing in discrete Gould transform (DGT). DGT has a wide range of applications in image processing and data hiding without any additional information. In particular the data or messages are inserted into the least significant bit to avoid distortion as much as possible.

In this paper, a new proposal of LCWT and DGT decomposition is established for reversible watermarking. Moreover, LCWT and DGT has many essential applications in image processing, steganography, watermarking, etc. Further the paper is structured as follows. In Section 2, the basic properties and definitions of LCWT and DGT. In Section 3, proposed method of newly introduced LCWT and DGT decomposition for image watermarking. In Section 4, the result anatomy of the proposed watermarking technique is elaborated. Section 5 states Conclusions and future works.

2. Methodology

2.1.Linear Canonical Wavelet Transform

A signal $f(t)$ with real parameter matrix A_0 is defined as [2,14]

$$F_{A_0}(u) = \int_{R^2} f(t)\, K_{A_0}(t,u)dt \quad (1)$$

With kernel

$$K_{A_0}(t,u) = \begin{cases} \frac{1}{\sqrt{ib_0}} \exp\left(i\frac{a_0t^2+d_0u^2-2tu}{2b_0}\right), b_0 \neq 0, \\ \sqrt{d_0}\exp\left(i\frac{c_0d_0u^2}{2}\right)\delta(u-d_0t), b_0 = 0 \end{cases} \quad (2)$$

where

$$A_0 = \begin{pmatrix} a_0 & b_0 \\ c_0 & d_0 \end{pmatrix} \quad (3)$$

$F_{A_0}(u)$is the LCT of $f(t)$[13-18], satisfying $a_0d_0 - c_0b_0$. From the LCT domain the canonical convolution with matrix parameter is defined as [2,20]

$$A_1 = \begin{pmatrix} a_1 & b_1 \\ c_1 & d_1 \end{pmatrix} \quad (4)$$

Of $f(t)$, $g(t) \in L^2(R)$ as follows

$$f(t)\Theta_{A_1}g(t) = \int_{-\infty}^{+\infty} g(\tau)\, T_\tau^{A_1} f(t)d\tau \quad (5)$$

$\Theta_{A_1}$is general canonical convolution operator $T_\tau^{A_1}f(t) = f(t-\tau)e^{-(ia_1/b_1)\tau(t-\tau/2)}$. From the above eqn.5that wavelet transform can be given as a classical convolution form [20]

$$W_f(a,b) = f(t) * \left(\frac{1}{\sqrt{a}}\,\psi\,\left(-\frac{t}{a}\right)\right) \quad (6)$$

Where $a \in R^+, b \in R, and\ \psi_{a,b}(t)$ of the mother wavelet $\psi(t)$. With matrix parameter A_1 the LCWT of signal $f(t)$ is defined as [19]

$$W_f^{A_1}(a,b) = f(t)\Theta_{A_1}\left(\frac{1}{\sqrt{a}}\,\psi\,\left(-\frac{t}{a}\right)\right) \quad (7)$$

$$= e^{-(ib^2/2).(a_1/b_1)} \int_{-\infty}^{+\infty}(f(t)e^{(it^2/2).(a_1/b_1)})\,\psi_{a,b}(t)dt \quad (8)$$

Where satisfying $a_1d_1 - c_1b_1 - 1$.

2.1.1. Properties of LCWT

Some of the basic properties of LCWT are noted below

i. Linear Property: If $f(t) = k_1f_1(t) + k_2f_2(t)$ and $f_1(t) \to W_{f_1}^{A_1}(a,b)$, $f_2(t) \to W_{f_2}^{A_1}(a,b)$ then it satisfy linear property, i.e.

$$W_f^{A_1}(a,b) = k_1W_{f_1}^{A_1}(a,b) + k_2W_{f_2}^{A_1}(a,b) \quad (9)$$

ii. Scaling Property: If $f(t) \to W_f^{A_1}(a,b)$, $f(s) = f(ct)$, then

$$W_{f(ct)}^{A_1}(a,b) = \frac{1}{\sqrt{c}}W_{f(t)}^{A'_1}(ca,cb) \quad (10)$$

Where c > 0 and

$$A'_1 = \begin{pmatrix} a'_1 & b'_1 \\ c'_1 & d'_1 \end{pmatrix} \quad (11)$$

Satisfying $a_1'/b_1' = (a_1/b_1)\,.\,(1/c^2)$

iii. Inner Product Theorem: If $f(t), g(t)\ and\ \Psi(\Omega)$ signifies the Fourier Transform of ψ(t). If$\Psi(\Omega)$ satisfies [2]

$$C_\psi = \int_{-\infty}^{+\infty}\frac{|\Psi(\Omega)|^2}{\Omega}d\Omega < \infty \quad (12)$$

Then

$$\int_{R^2} W_f^{A_1}(a,b)\,[W_g^{A_1}(a,b)]\,\frac{1}{a^2}da\,db = 2\pi\, C_\psi \int_{-\infty}^{+\infty} f(\mathrm{t})\, g(t)\, dt \quad (13)$$

Where $W_f^{A_1}(a,b)$ and $W_g^{A_1}(a,b)$ denotes LCWT.

iv. Parseval's relation: Let $f(t) = g(t)$, then Parsevals's possession cerebrate with LCWT is [2]

$$\int_{R^2}\left|W_f^{A_1}(a,b)\right|^2 \frac{1}{a^2}da\,db = 2\pi\, C_\psi \int_{-\infty}^{+\infty} f(\mathrm{t})\, g(t)\, dt \quad (14)$$

2.2.Discrete Gould Transform

Le et al proposed the concept of Discrete Gould Transform for an application of image processing [10-12]. DGT can be effectively used for data hiding method by a reversible difference expansion (DE). By changing the coefficient of least significant bit messages can be hidden with low distortion. The image DGT is given as

$$G_{u,v} = (-1)^{u+v}\binom{P}{u-v} \quad (15)$$

For u,v = 0,1,…..N-1 and p is integer with positive values

$$\binom{P}{u-v} = \frac{P!}{(u-v)!(p-u+v)!} \quad (16)$$

In lower triangular matrix the DGT has a constant unit values to identify the image edges with p = 1 and N = 2. Thus an image Z is defined as [3]

$$G = \begin{bmatrix} 1 & 0 \\ -1 & 1 \end{bmatrix} \quad (17)$$

The transformed image Z' is obtained by applying G to Z

$$Z' = GZG' \quad (18)$$

An cover image (Z) of size 2X2 is defined as

$$Z = \begin{bmatrix} Z_1 & Z_2 \\ Z_3 & Z_4 \end{bmatrix} \quad (19)$$

and DGT transformation of cover image is given as

$$Z_1' = Z_1 \quad (20)$$

$$Z_3' = Z_2 - Z_1 \quad (21)$$

$$Z_3' = Z_3 - Z_1 \quad (22)$$

$$Z_4' = Z_4 + Z_1 - (Z_2 + Z_3) \quad (23)$$

Now,

$$Z' = \begin{bmatrix} Z'_1 & Z'_2 \\ Z'_3 & Z'_4 \end{bmatrix} \quad (24)$$

And inverse discrete gould transform is defined as

$$Z = G^{-1}Z'(G')^{-1} \quad (25)$$

$$Z = \begin{bmatrix} Z'_1 & Z'_2 + Z'_1 \\ Z'_3 + Z'_1 & Z'_1 + Z'_2 + Z'_3 + Z'_4 \end{bmatrix} \quad (26)$$

From eqn-20 we can identify that pixel Z_1 and Z'_1 are not changed from their original values, thus Z_1 and Z'_1 pixel is used to calculate the difference for remaining pixels [7-10]. Now reversible watermarking is proposed by applying DGT to integer wavelet coefficient of the cover image [3].

For embedding the watermark information the original pixel Z'_4 is identified using eqn-29

$$Z_2' + Z_3' = Z_2 + Z_3 - 2Z_1 \quad (27)$$

$$Z_2 + Z_3 = Z_2' + Z_3' + 2Z_1 \quad (28)$$

Now substitute eqn-27 into eqn-23, we get

$$Z_4' = Z_4 + Z_1 - (Z_2' + Z_3' + 2Z_1) \quad (29)$$

$$Z_4 = Z_4' + Z_2' + Z_3' + Z_1 \quad (30)$$

To embed the watermarking bit (wb) multiply Z_4 by two Z_4

$$NZ_4 = 2 * Z_4 + wb \quad (31)$$

Now substitute NZ_4 in eqn instead of

$$Z_4' = NZ_4 + Z_1 - (Z_2' + Z_3' + 2Z_1) \quad (32)$$

$$Z_4' = NZ_4 - (Z_2' + Z_3' + Z_1) \quad (33)$$

Thus by substituting Z_4' in eqn-36 hybrid transformed block $Z^{tg}$is obtained. This process is redone for embedding all the watermark bits and hybrid watermarked image is generated. The hybrid watermarked image is obtained by embedding each and every watermark data bit. Using the eqn-26 inverse DGT is examined and again inverse LCWT is applied to obtain hybrid watermarked image $Z_{w.}$ Finally to the receiver end the watermarked image is sent without any additional information.

3. Proposed Method

This session the procedure of reversible watermarking technique for transmission of secured data in medical field is elaborated. Based on Discrete LCWT and DGT a new watermarking technique is proposed to decompose the original image. The watermarking embedding and extraction is computed as follows.

3.1. Embedding Methodology

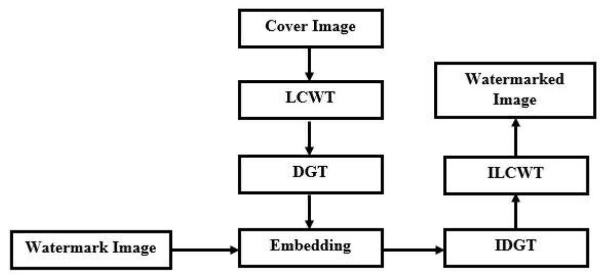


Fig. 1: Procedure for Watermarking

A cover image (Z) of size 512 x 512 is considered for secure transmission. The Linear canonical wavelet Transform (LCWT) is forensic for first level decomposition to obtain (LL) low frequency and high frequency subbands (LH, HL, HH) as shown in Fig 1. From the transformed image $Z^t$of size (H X W) a high frequency subband HL is divided into (L x L) size of non-overlapping (B) squared blocks [2].

$$B = \frac{H\ X\ W}{L^2} \quad (34)$$

Now apply DGT decomposition in HL subband of LCWT transformed image Z^t.

$$Z^t = \begin{bmatrix} Z_1 & Z_2 \\ Z_3 & Z_4 \end{bmatrix} \quad (35)$$

Z^{tg} is generated after applying DGT to each block of Z^t

$$Z^{tg} = \begin{bmatrix} Z_1' & Z_2' \\ Z_3' & Z_4' \end{bmatrix} \quad (36)$$

From eqn-33 original pixel $\boldsymbol{Z_4'}$is identified to embed the watermark bit information (wb), thus $Z^{tg}$is obtained. Using the eqn-26 inverse DGT is forensic for each block. Again inverse LCWT is established to obtain the watermarked image $Z_{w.}$

3.2. Extraction Methodology

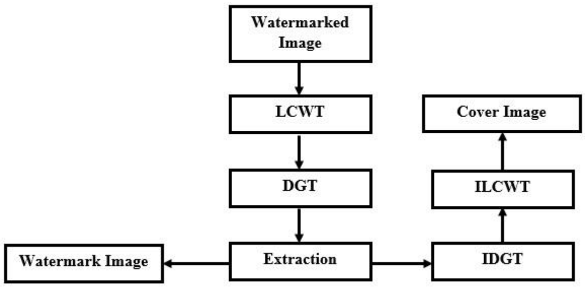


Fig. 2: Watermarking extraction procedure

The watermark binary (wb) has to be extracted from watermarked image $Z_w$at the receiver end as shown in Fig 2. Again first level LCWT is applied to Z_w. Then number of blocks has to be divided from high frequency subband and DGT is applied to each non-overlapping blocks. By the eqn-33 Z_4' is identified and watermark bit is obtained using modulo-division.

$$W = mod(NZ_4',2) \quad (37)$$

Without any additional information the original image will be restored after extracting the watermark bit. Thus original pixel parameter Z_4 is obtained by dividing final pixel value by two.

$$H = NZ_4' - wb \quad (38)$$

$$Z_4' = H/2 \quad (39)$$

Then the transformed pixel is decomposed with IDGT and again ILWCT is applied to get the original image without any loss. Hence without any additional information the original image is recovered from watermarked image.

4. Result and Discussion

In order to examine the proposed method, a grayscale image of size 512 x 512 are used and important characteristics of watermarking technique like reversibility, capacity, imperceptibility and robustness are measured. For the performance measure of proposed method an original image referred as X, watermarked image as X', position do pixel (c,d) and image size mxn.

4.1. Peak Signal to Noise Ratio (PSNR)

Measure to determine the quality of an original image with the degraded image. The PSNR value of the original image and watermarked image is calculated. For good image quality and low distortion PSNR value should be high. The PSNR value is calculated using the formula

$$PSNR = 10log_{10}\left(\frac{255^2}{MSE}\right) \quad (40)$$

4.2. Mean square error (MSE)

Mean square error of hybrid watermarked and original image, given as

$$MSE = \frac{\sum_{c=0}^{m-1}\sum_{d=0}^{n-1}\left(X(c,d)-(X'(c,d))\right)^2}{mXn} \quad (41)$$

$X(c,d)$and$X'(c,d)$ is original and watermarked image pixel value of (c,d) position [2].

4.3. Normalized Cross Correlation (NCC)

Evaluates the correlation among two images i.e. similarity value between original and watermarked images. The NCC value lies in range of 0 and 1. And both the images are same if the value is equal to 1.

$$NCC = \frac{\sum_{c=0}^{m-1}\sum_{d=0}^{n-1}\left(X(c,d).(X'(c,d))\right)}{\sum_{c=0}^{m-1}\sum_{d=0}^{n-1}(X'(c,d)^2)} \quad (42)$$

4.4. Structural Similarity Index (SSIM)

SSIM measures the image degradation by HVS based quality analysis. If the value is equal to 1 then images are equal, otherwise the value lies in range 0 to 1.

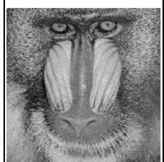
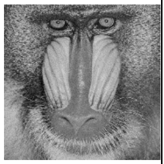
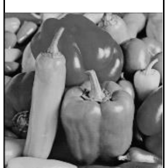
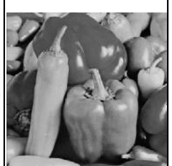
$$SSIM = i\,(c,d).co(c,d).s(c,d) \quad (43)$$

Where i referred to luminance, co is contrast and s structural component between original and watermarked images.

4.5. Comparison with IWT, DGT and Proposed Method

The reversible watermarking IWT and DGT is applied individually to the original image. The results are then compared with the proposed method (LCWT+DGT). The Hybrid transformation is examined to each image and the original image is reconstructed from the watermarked image. Some distortion is identified in DGT watermarked image ensures degradation in image visual quality. In IWT no degradation in the watermarked image and ensures better quality in the watermarked image, but while reconstructing the original image some loss in image quality is identified. In proposed hybrid transform scheme the watermarked image is obtained without any distortion and original image is reconstructed perfectly without any loss in image quality. From Table.1 the PSNR, NC and SSIM measurements between original and watermarked image shows the proposed method (LCWT+DGT) has higher PSNR value. Thus the hybrid transform is more reliable for secure and reversible transformation than other methods.

Table 1: Experimental results of the proposed method.

Cover Image	Watermark Image	Watermarked Image	PSNR & SSIM
			PSNR=64.53dB SSIM=0.9996
			PSNR=63.51dB SSIM=0.9996
			PSNR=59.41dB SSIM=0.9881

4.5. Existing Model Comparison

With the existing method of reversible watermarking technique the proposed system performance is compared. Normally reversible watermarking is executed in spatial or transform domain. In spatial domain whole image is used for embedding process, where in transform domain real pixel value is converted in another from and then total image is utilized for embedding process. Thus in order to attain more security and high embedding capacity in transform domain, the proposed method is compared with existing methods of transform domain.

The proposed hybrid model is analyzed with existing models like DGT and IWT. From the Table. 3it's noticed that existing method has some distortion and need some additional information to improve the original image with no loss. But in the proposed method to recover the original image no additional data is used and the original image is recovered without any loss. The embedding capacity is one of the main factor for image watermarking. The proposed method has high embedding capacity value as than the other existing technique with block size of 2X2. Even when the block size is increased to 4X4 the proposed method shows higher embedding capacity, where local existing method has lesser value.

NCC is one of the main factor in watermarking technique. Some sample cover images like Baboon, Lena and Pepper are examined with the existing model. From Table 2 the simulation results shown the proposed method has better NCC value than other existing method. For comparison of embedding capacity the proposed method is examined in transformed domain with some sample images like peppers, lena and baboon. The PSNR (db) values is compared with [10] [13] and [16]. The PSNR value of the proposed method shows high embedding capacity than other existing technique. Thus the proposed method yields a good result in embedding capacity and better restoration of original image without loss when compared to other existing transformed domain reversible water marking technique.

Table 2: Robustness analysis by calculating NC values of different attacks

Performance Measure	Baboon	Lena	Peppers
Salt & Pepper Noise	088	0.9091	0.9303
Gaussian Noise	0.9622	0.9219	0.9022
Speckle Noise	0.9483	0.9483	0.9288
Rotation (45)	0.9149	0.9671	0.9149

Table 3: Robustness analysis by calculating NC values of different attacks

IMAGE	DGT	IWT	IWT+DGT	PROPOSED
Baboon	38.7	35.92	64.56	64.53
Lena	23.75	53.34	60.12	63.51
Peppers	28.57	52.18	57.33	59.41

5. Conclusion

In this paper, a new reversible image watermarking technique is established to transfer the medical data securely in high frequency subbands. By applying LCWT to the original image high frequency subbands are attained. Using DGT the sample image information is embedded in high frequency subbands by identifying the non-overlapping blocks and transmitted to the sender. At the receiver the watermarked image is extracted as a lossless cover image without any additional information. The simulation results of the proposed method shows high increase in embedding capacity, PSNR and SSIM, also attains high robustness, capacity and withstands various attacks in image watermarking technique. Thus the hybrid scheme achieves watermarked image quality and lossless recovery of the original cover image compared to the other schemes.

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