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A Block based Reversible Medical Image Watermarking

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Abstract:In this paper we have proposed algorithms that are based on adaptive threshold method. Reversible watermarking scheme employed in this scheme improves Fourier Transform. First threshold map for image has been created and then image has been divided into different blocks. In last threshold map being set for each block. This improves image information storing capacity and original image can be obtained back. In this algorithm image can be recoded, embedded and transmitted simultaneously. The scheme can easily be used in e-diagnosis applications such as tele-consulting, tele-surgery and tele-diagnosis.

1.INTRODUCTION:

Analysis of ordinary gray scale images show that binary 0s and 1s are almost equally distributed in the first several ’lower’ bit planes . However, the bias between 0s and 1s gradually increases in the ’higher’ bit-planes. In this regard transformation of the image to frequency domain is expected to be more deliverable for obtaining a large bias between 0s and 1s. For this purpose and to avoid round-off error, we use the second generation wavelet transform, such as integer wavelet transform. This wavelet transform maps integer to integers and has been adopted by JPEG 2000 standard as well.

2.PROPOSED SCHEME

2.1 Generating Threshold Map (TMAP)

The proposed method divides the input image into blocks of size defined by the user and checks each block for underflow and overflow after embedding data. If the block produces underflow/overflow, value 0 is assigned in TMAP for that block and block is avoided in the watermark embedding process. On the other hand if the block successfully passes the underflow/overflow test, data are embedded and the imperceptibility of the watermark for this block is noted. If the peak signal to noise ratio (PSNR) of block is equal or greater than the predefined maximum value of peak signal to noise ratio ($PSNR_{MAX}$), block is declared as embeddable block and T_{MAP} is updated with the current value of threshold T. If the value of PSNR of block is less than $PSNR_{MAX}$ then, value of T is decremented by 1 and block is checked again for $PSNR_{MAX}$. The process continues until desired value of PSNR is achieved or value of threshold T approaches to T_{MIN}. The detailed procedure for finding T_{MAP} is defined as under:

1 Initialize T_{MAP} to an (M/B)×(N/B) zero matrix, where B is the user defined size of block and M, N are the height and width of the input image respectively.
2 Initialize T_{INIT} and T_{MIN} and $PSNR_{MAX}$ with the user defined values.
3 Set value of T as T_{INIT}.
4 Divide the input image I into blocks of size 8 X 8 Iteration.
5 Compute integer wavelet transform of block of image I using Cohen-Daubechies-Fauraue CDF(2,2) filters, performing decomposition up to 2nd level to obtain middle and high frequency wavelet sub-bands.
6 Apply the compression function using Eq. (1) on all horizontal, vertical and diagonal sub-band coefficients for which $|f| \geq T$.
7 Embed the watermark in all sub-band coefficients using Eq. (4), where h represents the original coefficient, b is watermark bit to be embedded and h’ is the watermarked coefficient.
8 Compute the inverse IWT of block(i,j) to obtain watermarked block block’(i,j), where i,j are the block row and column indices respectively.
9 In order to check that whether watermark embedding has not caused overflow/underflow, minimum and maximum pixel intensity values of watermarked block are computed. The status of block is the modified as under:

$$\mathrm{Block}^{*}(i,j)=\begin{cases} embeddable & if\ min\left(block'(i,j)\right) \geq 0\ and\ \max\left(block'(i,j)\right) \leq 255 \\ \text{not embeddable} & \text{otherwise} \end{cases} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2.1$$

10 Compute the PSNR of block∗(i,j) if it is embeddable.
11. If PSNR is found to be greater than or equal to maximum allowed $PSNR_{MAX}$, the threshold T is recorded in T_{MAX}.
12. Decrease the value of T by 1. This decrement in T will increase the PSNR of the block after embedding the watermark. This is due to the fact that when T is small, the coefficients alterations are small and good visual quality of marked image is achieved.

End of iteration

13. The iteration continues till T equals to T_{MIN}, where we obtain the matrix T_{MAP} containing threshold values of each block of input image I depending upon the properties of block.

The block diagram of generating the threshold map is shown in Fig. 2.1.

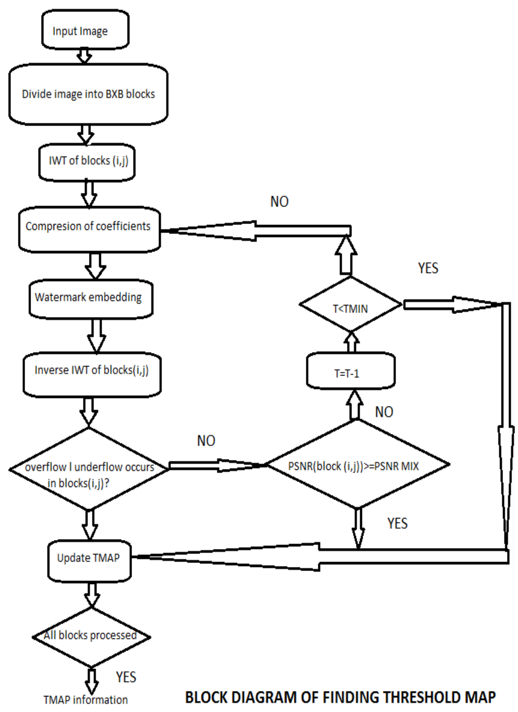


Fig 1

2.2 Watermark generation for proposed scheme

The proposed reversible watermarking method embeds the watermark which is generated from the following components:

• Error Vector (Z): If the value of coefficient is greater than or equal to user defined threshold T, it is compressed (via Eq. 2.1) and then expanded by the following equation.

$$E_q(f) = \begin{cases} f\,(|f| < T \;\; if\; sgn(f) X\,(2|f| - T) \\ \quad else\; |f| \geq T \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2.2$$

After then, the compounding error is calculated by the equation

$Z = |f| - |\, E_q\,(\, K_q\,(\, f\,)\,)\,|$ ……………………………2.3

. These errors are accumulated in vector Z. This vector help to recover the image exactly same as original at the extraction stage.

• Payload (P): This is user defined information. This can be any secret information related to image. For example binary logo in case of commercial images, patient information and diagnosis report in case of medical images or some secret codes describing the geographical information of territory in case of military images.

Thus overall watermark W will be the combination of the error vector Z and user defined payload P. In order to reduce the size of W, it is losslessly compressed with Arithmetic encoding algorithm.

2.3 Watermark embedding

Besides high capacity for payload, imperceptibility of image is highly desirable in reversible watermarking systems. Therefore embedding is performed only in horizontal, vertical and diagonal sub-bands which are composed of medium and high frequency coefficients. Further, data are embedded in first level coefficients. The detailed procedure for embedding payload plus overhead into the wavelet sub-bands is described below:

1. Find TMAP for input image I by implementing the steps as described in Section 2.1
2. Generate the watermark W as described in Section 2.2

Iteration

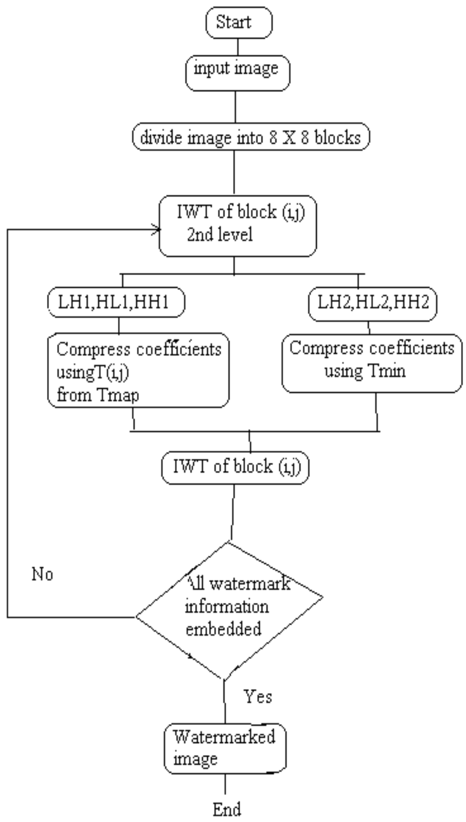
3. Divide the input image I into blocks of size 8 × 8.
4. Compute the 2D IWT of each block(i,j) up to level 2.
5. Get the threshold T(i,j) from TMAP for the corresponding block(i,j).
6. Apply the compression using Eq. (2.1) on both level 1 and level 2 coefficients. Compress coefficients of level 1 (HL1,LH1,HH1 sub-bands) using the threshold T(i,j) and level 2 (HL2,LH2,HH2 sub-bands) using the threshold T_{MIN}.
7. Now embed the watermark W into first level coefficients and TMAP into second level coefficients of block(i,j) using

$$H' = 2 \times h + b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.4$$

8. Compute inverse IWT to get the watermarked block'(i,j).
9. The process will be continued until all watermark W is completely embedded into selected Blocks.

End of iteration

10. The marked image gives the final watermarked image.



Block diagram of proposed embedding algorithm

Fig 2

2.4 Watermark Extraction

The watermark extraction process is described step by step as follow:

1. Divide the watermarked image into blocks of size 8 × 8 .
2. Compute 2D IWT of block(i,j) using CDF filters and decompose the image up to level 2;
3. Extract watermark from first level coefficients and the TMAP from 2nd level coefficients using equation b’ = LSB(h’).
4. The process will be continued until all the watermark information is extracted from blocks.
5. Decompress the extracted watermark bitstream W’ using arithmetic decoding algorithm to restore the original bitstream.
6. Once W’ has been decompressed, recover the error vector Z’ and payload P’.

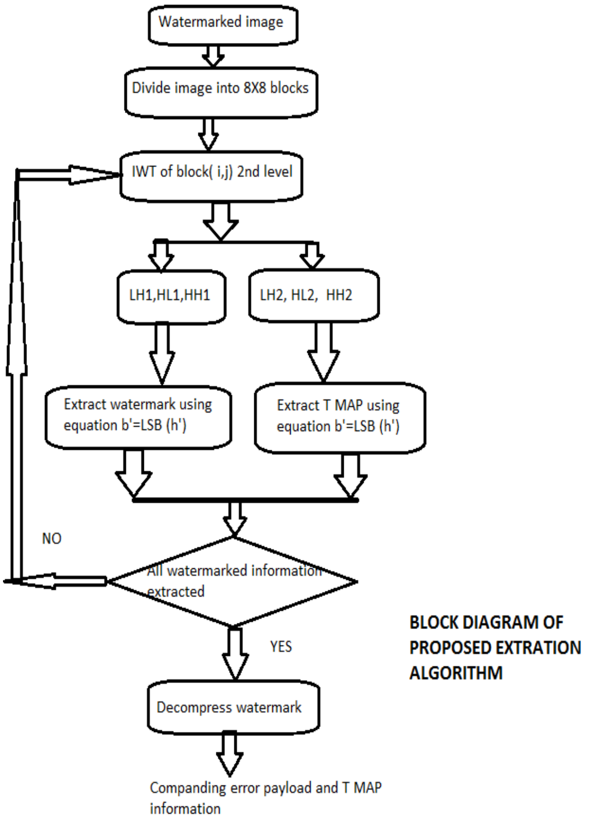


Fig 3.

2.5 Recovery of Original Image

The original image is recovered by the following steps:

1.Read the watermarked image.

Iteration

2. Divide the watermarked image I’ into blocks of size B × B;
3. Compute the 2D IWT of block(i,j) using CDF filters and decompose it up to 2nd level;
4. Recover the coefficients by using Eq. (2.5);

$$H = \frac{h' - b}{2} \quad \ldots\ldots\ldots\ldots \quad \ldots 2.5$$

5. Expand the coefficients by using Eq. (2.2). The first level coefficients are expanded by using threshold T(i,j) and second level coefficients with T_{MIN};
6. Obtain the original coefficients by adding the companding errors in recovered coefficients.
7. Compute the inverse IWT to get the original block(i,j).
8. The process will be continued until all the blocks are processed. The resultant image will be same as the original and can further be used for diagnosis by the physician.

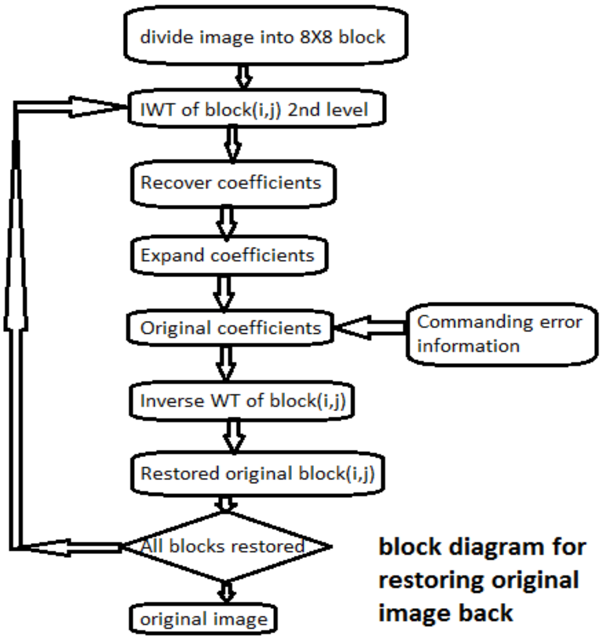


Fig 4

3. Experimental Results and Discussions

In our experiments, beside natural images we have also used the medical images of different modalities such as Computed Tomography (CT), Magnetic Resonance images (MRI), Xray and Ultrasound for showing the validity of proposed method.

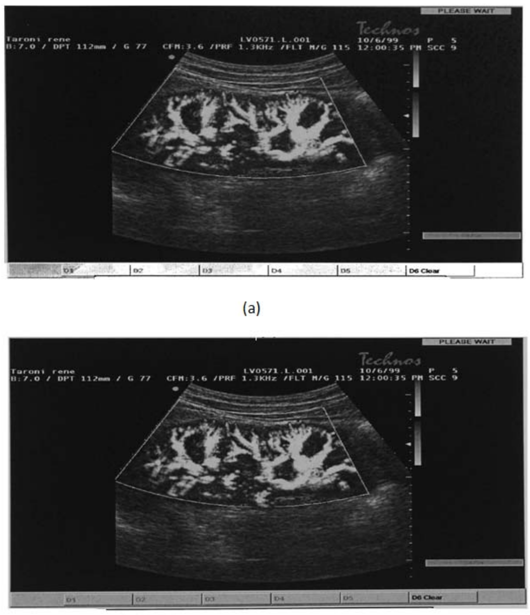


Fig 5

Image used in the experiments is shownin Fig.5 . The images are resized to 512 × 512 pixels before applying the algorithm. We applied the reversible watermarking method as described in Section 2.2 to secretly hide the payload and overhead data in the images. IWT with wavelet CDF(2,2) is used for transformation of image into wavelet domain. The fixed values of TMIN and PSNRMAX are used as 2 and 42.0 dB respectively in all experiments. However, the value of TINIT is selected in the range of {2 − 15}. The value of PSNRMAX can be varied as per desired level of imperceptibility in particular application. The value of PSNRMAX directly control the quality of watermarked image. Higher the value of PSNRMAX better the quality of watermarked image. The watermarked version of the cover images shown in Fig. 5.6 are given in Fig. 5.7. The initial value of threshold (TINIT) is taken 15 and block size of 8 × 8 are used for these watermarked images.

3.1 Improvement Achieved

As described in Section 2.1, the proposed method divides the image into blocks of size defined bythe user and checks each block for the occurrence of underflow/overflow. The proposed method then embeds the watermark in those blocks which do not cause underflow/overflow, thereby, avoiding the pre-process step of histogram modification required in most reversible watermarking techniques.

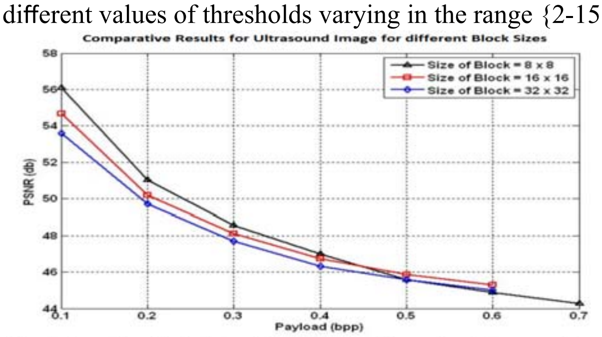
In this method, we use thresholds in the range of {1−15}, so 4 bits will be sufficient to convert each value of threshold into binary form recorded in T_{MAP}. The number of bits required for storing $T_{5.}$ can be found

$$\text{bits} = (N/B)^2/4 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2.6$$

where N and B are the image and block sizes respectively. From Eq.2.2, it can easily be calculated that, for the image of size 512 × 512 with block size of 8 × 8, 16 × 16, 32 × 32, the number of bits required for storing TMAP will be 16384, 4096 and 1024 respectively. Further by using AT instead of FT, the proposed method achieves higher PSNR for same payload or higher payloads for same PSNR.

3.3 Analysis of TMAP

In order to further elaborate the working of proposed method, the threshold maps for all cover medical images Fig. 2.1 using different block sizes of 8×8, 16×16 and 32×32. The blocks having black color in threshold maps indicate that blocks are not selected for embedding whereas other blocks having different gray values indicate the different values of thresholds varying in the range {2-15}.



Graph shows the effect of changing block size. The payload decrease with increase in block size

Image Type	Histogram Modification	Proposed Tmap (S=8X8)	Proposed Tmap (S=16X16)	Proposed Tmap (BS = 32X32)
Ultrasound	649	16384	4096	1024

Table 2.1: Comparison in terms of overhead (number of bits) between proposed Method

4. Summary

We have proposed a reversible watermarking system based on companding and adaptive threshold embedding method. The method has potential applications in military, medical and law enforcement related image processing. The proposed method provides better tradeoff between capacity and imperceptibility of a watermarking system compared to the existing schemes. It is also able to restore the original cover image. Further, we have also performed experiments by embedding the medical diagnosis reports of patients in medical images to show the potential of proposed scheme for application in health care systems. The proposed scheme allows the simultaneous storage and transmission of electronic patient record which can be extracted at the receiving end without degrading the original image.

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