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A Digital Image Multi-watermarking using three level wavelet decomposition

Thamilvalluvan.B[1], Chakravarthy.B[2], Suresh.R[3], Dinesh kumar.T.R[4]

[1,2,3,4]Asst.Professor / Dept of ECE/ Vel Tech / Chennai – 62.

***Abstract*-Digital watermarking is an application associated with copyright protection. The idea behind digital watermarking is to create a unique identifier and embed it on an image in order to be able to prove that the image is the property of the rightful owner. The two types of digital watermarking are visible and invisible. In this paper, invisible multi-watermarking scheme is proposed, in which three binary watermarks are embedded in a grayscale digital image. The original digital image was subjected to discrete wavelet transform and then the approximation sub image was decomposed into non overlapping blocks. Finally, the multi-watermark embedding is carried out by modifying the fractional part values of the selected block pixels. A scheme was also developed for multi-watermarking extraction. The experimental results shows that multi-watermarks are robust and immune to attacks.**

Keywords: Multi-watermarks, DWT, Robust.

I. Introduction

With the widespread distribution of digital information over the World Wide Web (www), the protection of intellectual property rights has become increasingly important. The new technologies enable us to store, transfer and process digital content with less time, lower complexities and better efficiency. However, digitization also brings in disadvantages like illegal reproduction and distribution of digital content. Internet plays a very crucial role in circulation of illegal and unauthorized digital content. This increases the risk of violating owner right and hampering authenticity of a digital content. One way to protect digital content against illegal reproduction and distribution is to embed some extra information called watermark into it. A watermark should be embedded in such a way that it remains detectable as long as the perceptual quality of the digital content stays at an acceptable level.

The spatial and transform domains are two common methods for image watermarking. Embedding the watermark into the transform-domain generally helps to increase the imperceptibility, security, and robustness. Therefore, at present, most of image watermarking methods are in the transform domain, where DFT, DCT, DWT are three main transform methods used.

According to the number of watermarks to be embedded, the digital watermarking can be classified into the single watermarking scheme and the multi-watermarking scheme. Compared to the former, the latter has much greater applications and can be used to solve the problems of multiple ownership or copyright. According to the visibility of human eye the watermarks can be classified as visible and invisible. A visible watermark on a file or image is very similar to a corporation's logo on its letterhead. It is basically a semitransparent identifier (i.e. logo) that is used to show the ownership of the file or image. An invisible watermark is an identifier that is imbedded into a file or image but is completely invisible to the eye.

In this paper, a novel and robust invisible digital image multi-watermarking scheme in the Discrete Wavelet Transform (DWT) domain is proposed, in which three binary watermarks are embedded into a grayscale host image simultaneously. A series of experimental results demonstrate that the proposed multi-watermarking scheme has ideal performance.

II. RELATED THEORIES

1. BASICS OF WATERMARKING

A digital watermark can be described as a visible or preferably invisible identification code that is permanently embedded in the data. A general definition can be given: "Hiding of a secret message or information within an ordinary message and the extraction of it at its destination".

The first distinction that one needs to do in the study of watermarking for digital images is the notion of visible watermarks versus invisible ones. The first ones are used to mark, obviously in a clearly detectable way, a digital image in order to give a general idea of what it looks like while preventing any commercial use of that particular image. The purpose here is to forbid any unauthorized use of an image by adding an obvious identification key, which removes the image's commercial value. On the other hand, invisible watermarks are used for content and/or author identification in order to be able to determine the origin of an image. They can also be used in unauthorized image's copies detection either to prove ownership or to identify a customer. The invisible scheme does not intend to forbid any access to an image but its purpose is to be able to tell if a specified image has been used without the owner's formal consent or if the image has been altered in any way.

2. METHODS OF WATERMARKING

A. Spatial Domain Method

The spatial domain is the normal image space, in which a change in position in I directly projects to a change in position in space. Distances in I (in pixels) correspond to real distances (*e.g.* in meters) in space. This concept is used most often when discussing the frequency with which image values change, that is, over how many pixels does a cycle of periodically repeating intensity variations occur. One would refer to the number of pixels over which a pattern repeats (its periodicity) in the spatial domain. Here we use Least Significant bit (LSB)method.

B. Transform Domain Method

The produce of high quality watermarked image is by first transforming the original image into the frequency domain by the use of Fourier, Discrete Cosine Transform (DCT) or Discrete Wavelet transforms (DWT) for example. With this technique, the marks are not added to the intensities of the image but to the values of its transform coefficients. Then inverse transforming the marked coefficients forms the watermarked image. The use of frequency based transforms allows the direct understanding of the content of the image; therefore, characteristics of the human visual system (HVS) can be taken into account more easily when it is time to decide the intensity and position of the watermarks to be applied to a given image.

3. DISCRETE WAVELET TRANSFORM

The transform of a signal is just another form of representing the signal. It does not change the information content present in the signal. The Wavelet Transform provides a time-frequency representation of the signal. A wave is an oscillating function of time or space and is periodic. In contrast, wavelets are localized waves. They have their energy concentrated in time or space and are suited to analysis of transient signals. While Fourier Transform and STFT use waves to analyze signals, the Wavelet Transform uses wavelets of finite energy.

FIG 3.1: WAVELET

The DWT splits the signal into high and low frequency parts. The high frequency part contains information about the edge components, while the low frequency part is split again into high and low frequency parts. After the first level of decomposition, there are 4 sub-bands: LL1, LH1, HL1, and HH1. For each successive level of decomposition, the LL sub band of the previous level is used as the input. To perform second level decomposition, the DWT is applied to LL1 band which decomposes the LL1 band into the four sub-bands LL2, LH2, HL2, and HH2. To perform third level decomposition, the DWT is applied to LL2 band which decompose this band into the four sub-bands – LL3, LH3, HL3, HH3. This results in 10 sub-bands per component. LH1, HL1, and HH1 contain the highest frequency bands present in the image tile, while LL3 contains the lowest frequency band. The three-level DWT decomposition is shown in Fig.3.2.

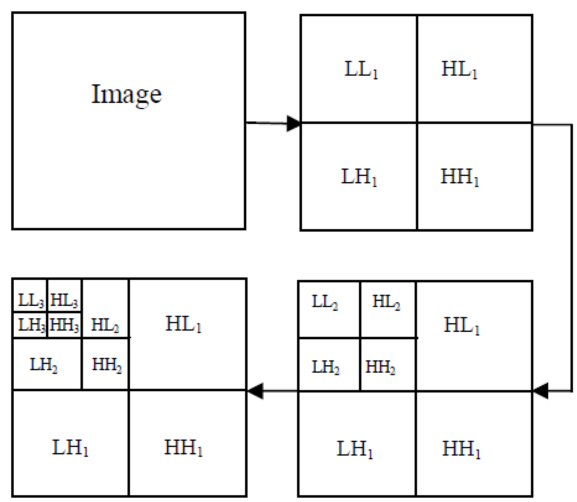

Fig 3.2: 3-LEVEL DISCRETE WAVELET TRANSFORM

Here haar discrete wavelet transform is used. Haar wavelet is discontinuous, and resembles a step function.

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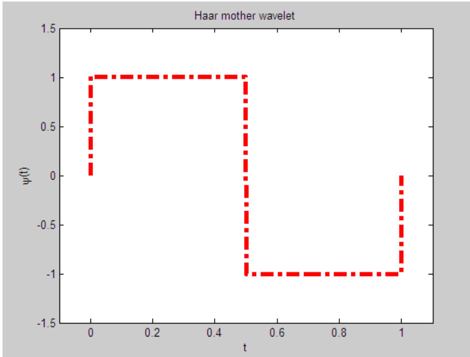


FIG 3.3: THE HAAR MOTHER WAVELET (Ψ(t))

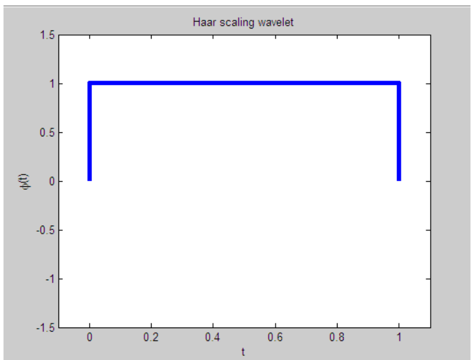


FIG 3.4: THE HAAR SCALING WAVELET (Φ(t))

The Haar wavelet's mother wavelet function Ψ(t) can be described as:

$$\psi(t) = \begin{cases} 1 & 0 \le t < \frac{1}{2} \\ -1 & \frac{1}{2} \le t < 1 \\ 0 & \text{otherwise,} \end{cases}$$

and its scaling function Φ (t) can be described as:

$$\phi(t) = \begin{cases} 0 & 0 \le t < 1 \\ 1 & \text{otherwise.} \end{cases}$$

DWT is currently used in a wide variety of signal processing applications, such as in audio and video compression, removal of noise in audio, and the simulation of wireless antenna distribution.

III. EXISTING SYSTEM

In existing system, discrete wavelet transform is used in Decomposition of original images into sub images. Here the image is decomposed up to **two level.** The 3D watermarking sequence is generated. The multiple watermarks are synchronously embedded. The multi-watermarks embedded is extracted by going through the reverse processes as followed in multi-watermarking embedding.

IV.PROPOSED SYSTEM

1. MULTI WATERMARKING GENERATION

Each of the K watermarks W_k= {$W_k(i,j)$=0/1}, k=1,2…,K is a binary image with size of $N \times N$. From these 2-D K watermarks, we can construct a 3-D watermarking sequence W_t:
W_t={ $W_k(i,j,1:K)$=[$W_1(i,j)$, $W_2(i,j)$,….. $W_k(i,j)$]},
$1 \le i \le N, 1 \le j \le N$
Where $W_t(i,j,z), 1 \le z \le K$ is the 3-d watermarking pixel located at coordinate (i,j,z).

2. MULTI WATERMARKING EMBEDDING

The original digital image is a grayscale image denoted as F = {0 ≤ f (i,j)≤255} with size of M×M. Without loss of generality, the original image size M×M and watermarking size N×N satisfies M /N=r, r is an integer greater than one.

Step 1: Decompose the original image F by applying L level DWT, and obtain a L-level approximation sub-image FL with size of $M/2^L \times M/2^L$.

Step 2: Split the approximation sub-image FL into multiple non-overlapping blocks with size of n×n, and calculate its uniformity d of each block based on the following equation

$$d(B_k) = \frac{1}{n^2} \bullet \sum_{(i,j)\in B_k} \frac{|f(i,j) - m_k|}{m_k^{1+\alpha}}$$

Step 3: Select the blocks with the largest block uniformity, and denoted as BFL s(s=1, 2, …, S). The selected block number S meets the requirement that the pixel number sum of selected blocks just equals to the pixel number of binary watermark to be embedded.

Step 4: Extract the fractional part of each pixel value from the selected blocks. BF_L^S:$DBF_L^S(i,j)=BF_L^S(i,j)$-floor($BF_L^S(i,j)$)(s=1,2,…,S).Here, function floor(x) denotes to round variable x to the nearest integer towards minus infinity.

Step 5: Embed the multi-watermarks by modifying the value of DBFL s(i, j) based on the following discrete algorithm,
If 0≤DBF_L^S (i, j)<0.5,
DBF_L^S(i, j)=0.25, Lg(i, j)=Dec(wT(i, j, 1: K));
else
DBF_L^Si, j)=0.75;
If mod(Dec(W_t (i, j, 1: K)), 2)=0
Lg(i, j)=Dec(W_t(i, j, 1: K))+1;
else

$Lg(i, j)=Dec(W_t(i, j, 1: K))-1;$
end
end
where function Dec(x) denotes to convert a binary vector x to the decimal integer.

Step 6: Recombine the modified fractional part $DBF_L^S(i,j)$ with its original integer part and form the new S blocks, $BF'_L{}^S$:$BF'_L{}^S(i,j)=DBF_L^S(i,j)+floor(BF_L^S(I,j))$ (s=1,2,…,S).

Step 7: Replace the original old blocks BF_L^S with these new blocks $BF'_L{}^S$ and obtain a new approximation sub-image F'L.

Finally, the watermarked image is created from the new approximation sub-image F'L and the original detail sub images by executing L-level inverse wavelet transform.

3. MULTI WATERMARKING EXTRACTION

Step 1: Decompose the tested image T_F with size of M*M by applying 3 level DWT, and obtain an approximation sub-image T_F_L.

Step 2: Split the approximation sub-image T_F_L into multiple non overlapping blocks with size of n*n in the same way as it was done before and select the corresponding blocks $T\_BF_L^S$ (s=1,2,….,S) according to the position information recorded in the watermarking embedding process.

Step 3: Extract the fractional part of each pixel for blocks $T\_BF_L^S$:$T\_DBF_L^S(i,j)=T\_BF_L^S(I,j)-floor(T\_BF_L^S(i,j))$ (s=1,2,….S).

Step 4: Recover the multi-watermarks w_k^* (k=1,2…K) based on the following discrete operation according to the fractional part value $T\_BF_L^S(i,j)$ of the selected blocks and the logical table Lg.

If $0\leq T\_BF_L^S(i,j)<0.5$,
    $W_t(I,j,1:k)=Bin(lg(I,j));$
Else
    If mod(Dec(lg(I,j)),2)=0
        $W_t(I,j,1:k)=Bin(lg(i,j)+1);$
    Else
        $W_t(I,j,1:k)=Bin(lg(i,j)-1);$
    End
End

$W_1^*(I,j)=W_t(i,j,1)$, $W_2^*(i,j)=W_t(I,j,2)$,…,
$W_k^*(i,j)= W_t(i,j,K)$

Where function Bin(x) denotes convert the decimal integer x to a binary vector.

V. EXPERIMENTAL RESULTS

We have used three binary images with size of 32×32 are selected as digital watermarks to be embedded. They are named as *w*1, *w*2 and *w*3, respectively. The original image is a grayscale 8-bit woman image of size 512×512 and is normalized first before embedding watermark. Considering the size of original image and actual watermark, a 3-level wavelet decomposition and reconstruction was applied to the image. The quality of watermarked image is evaluated by peak signal to noise ratio (*PSNR*) and the objective evaluation of extracted watermarking results uses the error rate defined as below, respectively.

$$PSNR = 10\times\log_{10}\left(1^2/MSE\right)\ (\text{dB})$$

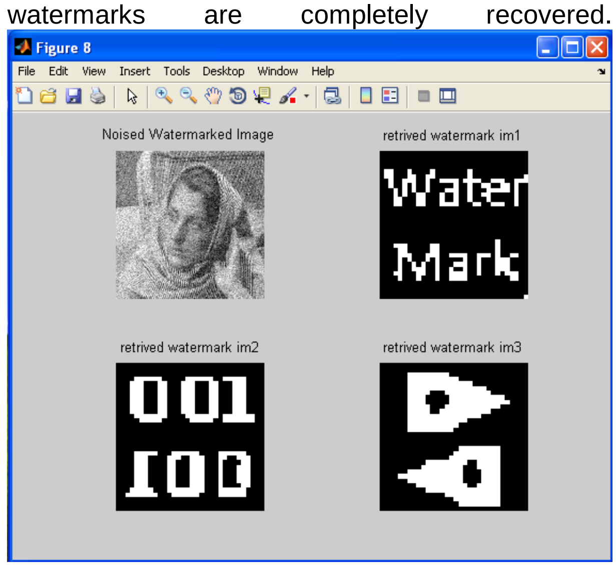
$$MSE = \sum_{i=1}^{N}\sum_{j=1}^{N}\left(f(i,j)-f^*(i,j)\right)^2 \Big/ N^2$$

where *f*(*i*, *j*) and *f* *(*i*, *j*) represent the pixel values of the original and watermarked image, respectively. T_b represents the total pixel number of the embedded digital watermark, T_{error} represents the total error pixel number occurred in the extracted watermark.

The robustness of the proposed multi-watermarking scheme is evaluated below by performing several typical image processing attacks.

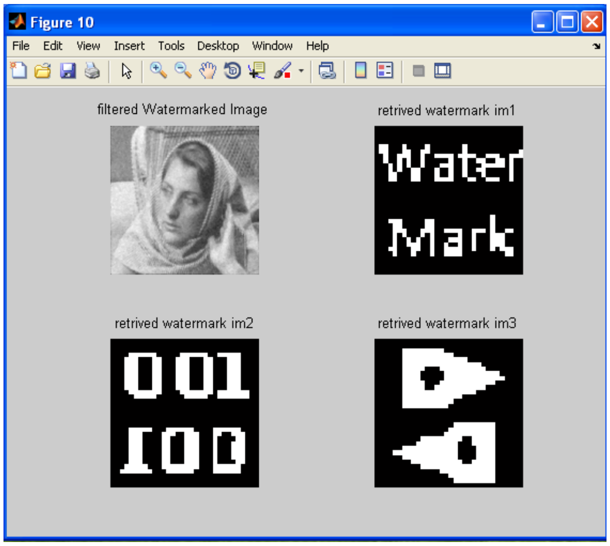
A. Noise Addition

The watermarked woman image added by Gaussian noise with mean of 0 and variance of 0.01. The results shows that the watermarked woman image is very noisy and the perceptual quality degrades obviously. It is shown that the watermarks are completely recovered.



B. Median Filtering

The watermarked woman image filtered by median filter with window size of [7×7]. After low-pass filtering, lot of detail information is lost and the *PSNR* of the watermarked image reduces. It is shown that the watermarks are completely recovered.



VI. CONCLUSION

In this paper, an image watermarking technique based on a 3-level discrete wavelet transform has been implemented. This technique can embed the invisible watermark into salient features of the image. Experiment results indicate that the three level DWT provide better performance than 1-level and 2- level DWT. All the results obtained for the recovered images and the watermark are identical to the original images.

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Authors Profile

B.Thamilvalluvan received the **B.E.** degree in electronics and communication engineering from the Pallavan college of Engineering, kanchipuram. TamilNadu, India, in 2008 and **M.E.** in electronics and communication engineering (Communication Systems) in Ranipet Engineering college, Vellore, TamilNadu, India in 2011. Research interest includes Digital Image Processing

P.Chakravarthy received the **B.E.** degree in electronics and communication engineering from the Veltech College of Engineering, Chennai, India, in 2009 and **M.E.** in electronics and communication engineering (Applied electronics) GCT in Anna University of technology, Coimbatore, India. His Research interest includes Digital Image Processing.

R.Suresh received the **B.E.** degree in electronics and communication engineering from the DR.M.G.R College of Engineering, Chennai, India, in 2006 and **M.TECH** in electronics and communication engineering (VLSI Design) in Sathyabama university, chennai, India in 2009. His Research interest includes Digital Image Processing.

T.R.Dineshkumar received the **B.E.** degree in Electrical and electronics engineering from the Sathyabama university, chennai, India in 2007 and **M.TECH** in electronics and communication engineering (VLSI Design) in Sathyabama university, chennai, India in 2009. His Research interest includes Digital Image Processing.