Digital Image Watermarking Techniques of Spatial and Frequency Domain Hybrid Platform

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Abstract—In the today's high scale communication of data there is a pressing need is generated for protection of the data information from many of the illegal duplication and modifications. For this purpose image watermarking is getting a very growing focus for a solution to the theft and tampering by involving the applications of advanced digital image processing operations to watermark copyright and authentication information inside the image content. Presently we are giving implementation results for a spatial and frequency domain hybrid platform watermarking techniques that are involved in designing a secure image data transmission. We have focussed on both spatial and frequency domain aspects in image watermarking and proposed various hybrid scheme which have currently proving themselves as more robust and almost invariant to some of the image attacks.

Keywords-- Watermarking, image processing, DCT, DWT, SVD and image encryption, security.

1. Introduction:
Image watermarking is a signal that is embedded in a image data permanently such that it can be extracted by dewatermarking using some operations for checking the authenticity of data or user. The watermark is inseparable from the host image and it should be robust enough to resist any modifications along with preserving the image quality. In this way the watermarking helps in keeping intellectual properties accessible while being permanently water marked. In our present article we have focused on watermarking techniques and checked their robustness against environmental distortions during the storage and transmission of watermarked image. In this paper we have provided a review on DCT,DWT and SVD based watermarking scheme and their various hybrid SVD-DCT-DWT watermarking approaches in gray image watermarking to develop a robust algorithm against several image attack. We have found that two different watermarking technique named as DCT-SVD,DWT-SVD can further be combined to give better watermarking results. In this paper in section 1 we have given description of the DWT, DCT and SVD method and how they are used in image watermarking. In section 2 we have given details of different hybrid watermarking schemes that has been applied to develop a platform for modern image copyright protection schemes.

1.1 Discrete Wavelet Transform:
Discrete Wavelet Transform (DWT) is a multiresolution analytical approach of time-frequency and can describe partial characteristics of time and frequency domains. The basic thought is to decompose the image to sub images with different space and frequency, then, the coefficient is processed [4]. The DWT can be implemented as a multistage transformation. An image is decomposed into four subbands denoted LL, LH, HL, and HH at level 1 in the DWT domain, where LH, HL, and HH represent the finest scale wavelet coefficients and LL stands for the coarse-level coefficients.

1.1.1 2D Discrete Wavelet Transform
The 2D DWT is computed by performing low-pass and high-pass filtering of the image pixels as shown in Figure 1. In this figure, the low-pass and high-pass filters are denoted by h and g, respectively. This figure depicts the three levels of the 2D DWT decomposition. At each level, the high-pass filter generates detailed image pixels information, while the low-pass filter produces the coarse approximations of the input image [7]. At the end of each low-pass and high-pass filtering, the outputs are down-sampled by two (↓ 2). In order to provide 2D DWT, 1D DWT is applied twice in both horizontal and vertical filtering. In other words, a 2D DWT can be performed by first performing a 1D DWT on each row, which is referred to as horizontal filtering, of the image followed by a 1D DWT on each column, which is called vertical filtering.

There are different approaches to implement 2D-DWT such as traditional convolution-based and lifting scheme methods. The convolution methods apply filtering by multiplying the filter coefficients with the input samples and accumulating the results. Their implementation is similar to the Finite Impulse Response (FIR) implementation. This kind of implementation needs a large number of computations.
2. Related Work:
In 2011, Manjit Thapa et. al presented their work related to secure digital image watermarking techniques. In this work, they stated that digital watermarking was used to hide the information inside a signal, which cannot be easily extracted by the third party. Its widely used application was copyright protection of digital information. It was different from the encryption in the sense that it allowed the user to access, view and interpret the signal but protect the owner-ship of the content. One of the current research areas was to protect digital watermark inside the information so that ownership of the information cannot be claimed by third party. With a lot of information available on various search engines, to protect the ownership of information is was a crucial area of research. In latest years, several digital watermarking techniques were presented based on discrete cosine transform (DCT), discrete wavelets transform (DWT) and discrete Fourier transforms (DFT). In this work, we proposed an algorithm for digital image watermarking technique based on singular value decomposition; both of the L and U compo-nents are explored for watermarking algorithm. This technique referred to the watermark embedding algorithm and watermark extracting algorithm. The experimental results proved that the quality of the watermarked image was excellent and there was strong resistant against many geometrical attacks.

In 2012, Kaushik Deb proposed their work related to combined dwt-dct based digital image watermarking technique for copyright protection. Their work stated a combined DWT and DCT based watermarking technique with low frequency watermarking with weighted correction is proposed. DWT has excellent spatial localization, frequency spread and multi-resolution characteristics, which were similar to the theoretical models of the human visual system (HVS). DCT based watermarking techniques offered compression while DWT based watermarking techniques offered scalability. These desirable properties were used in this combined watermarking technique. In the proposed method watermark bits were embedded in the low frequency band of each DCT block of selected DWT sub-band. The weighted correction was also used to improve the imperceptibility. The extracting procedure reversed the embedding operations without the reference of the original image. Compared with the similar approach by DCT based approach and DWT based approach, the experimental results showed that the proposed algorithm apparently preserved superior image quality and robustness under various attacks such as JPEG compression, cropping, sharpening, contrast adjustments and so on.

In 2012, Yusuf Perwej et. al proposed their work related to an adaptive watermarking technique for the copyright of digital images and digital image protection. In this work they stated that internet as a whole does not use secure links, thus information in transit may be vulnerable to interruption as well. The important of reducing a chance of the information being detected during the transmission is being an issue in the
real world now days. The Digital watermarking method provides for the quick and inexpensive distribution of digital information over the Internet. This method provides new ways of ensuring the sufficient protection of copyright holders in the intellectual property dispersion process. The property of digital watermarking images allows insertion of additional data in the image without altering the value of the image. This message is hidden in unused visual space in the image and stays below the human visible threshold for the image. Both seek to embed information inside a cover message with little or no degradation of the cover-object. In this work investigate the following relevant concepts and terminology, history of watermarks and the properties of a watermarking system as well as a type of watermarking and applications. We are proposing edge detection using Gabor Filters. In this work they proposed least significant bit (LSB) substitution method to encrypt the message in the watermark image file. The benefits of the LSB are its simplicity to embed the bits of the message directly into the LSB plane of cover-image and many techniques using these methods. The LSB does not result in a human perceptible difference because the amplitude of the change is little therefore the human eye the resulting stego image will look identical to the cover image and this allows high perceptual transparency of the LSB. The spatial domain technique LSB substitution it would be able to use a pseudo-random number generator to determine the pixels to be used for embedding based on a given key. They were using DCT transform watermark algorithms based on robustness. The watermarking robustness have been calculated by the Peak Signal to Noise Ratio (PSNR) and Normalized cross correlation (NC) is used to quantify by the Similarity between the real watermark and after extracting watermark.

In 2013 Bhupendra Ram et. Al. (IEEE) proposed their work related to digital image watermarking technique using discrete wavelet transform and discrete cosine transform. In this work they stated that digital watermarking has been proposed as a viable solution to the need of copyright protection and authentication of multimedia data in a networked environment, since it makes possible to identify the author, owner, distributor or authorized consumer of a document. In this work a new watermarking technique to add a code to the real watermark and after extracting watermark.

3. Singular Value Decomposition:
Singular value decomposition of the matrix is a linear algebra in one of the most basic tools, which is firstly proposed by the Beltrami and Jordan in the 1870s, and widely used in image compression and signal processing after the 1960s. The basic idea behind the SVD-based watermarking techniques is to find the SVD of the cover image or each block of the cover image, and then modify the singular values to embed the watermark [3].

In SVD transformation, an image can be viewed as a matrix with nonnegative scalar entries. The SVD of an image A with size m × m is given by

\[ I = U S V^T \]

where U and V are orthogonal matrices, and S = diag(\(\alpha_i\)) is a diagonal matrix of singular values \(\alpha_i, i = 1, \ldots, n\), which are arranged in decreasing order. The columns of V are the right singular vectors, whereas the columns of U are the left singular vectors of image I.

It is noticeable that the unique property of the SVD transform is that the potential N2 degrees of freedom or samples in the original image now get mapped into [1]:

\[ S \Rightarrow N \text{Degrees of freedom} \]
\[ U \Rightarrow N(N - 1)/2 \text{ Degrees of freedom} \]
\[ V \Rightarrow N(N - 1)/2 \text{ Degrees of freedom} \]

Totalling N2 degrees of freedom.

SVD is an optimal matrix decomposition technique in a least square sense that it packs the maximum signal energy into as few coefficients as possible. It has the ability to adapt to the variations in local statistics of an image [2].

3.1 Properties of SVD
Generally a real matrix A has many SVs, some of which are very small, and the number of SVs which are non-zero equals the rank of matrix A [3]. SVD has many good mathematical characteristics. Using SVD in digital image processing has some advantages [5]:
i) The size of the matrices from SVD transformation is not fixed and can be a square or a rectangle.
ii) The SVs (Singular Values) of an image have very good stability, i.e. when a small perturbation is added to an image, its SVs do not vary rapidly;
iii) SVs represent algebraic image properties which are intrinsic and not visual.
Due to these properties of SVD, in the last few years several watermarking algorithms have been proposed based on this technique. The main idea of these approaches is to find the SVD of a cover image and then modify its singular values to embed the watermark. Some SVD-based algorithms are purely SVD-based in a sense that only SVD domain is used to embed watermark into image. Recently some hybrid SVD-based algorithms have been proposed where different types of transforms domain including Discrete Cosine Transform, Discrete Wavelet Transform, Fast Hadamard Transform etc. have been used to embed watermark into image.

4. The DCT Transform
The DCT transforms have been extensively used in many digital signal processing applications. In this section, we introduce the DCT transforms briefly, and outline their relevance to the implementation of digital watermarking. The discrete cosine transforms is a technique for converting a signal into elementary frequency components [6]. It represents an image as a sum of sinusoids of varying magnitudes and frequencies. With an input image, x, the DCT coefficients for the transformed output image, y, are computed according to Eq. 1 shown below. In the equation, x, is the input image having N x M pixels, x(m,n) is the intensity of the pixel in row m and column n of the image, and y(u,v) is the DCT coefficient in row u and column v of the DCT matrix.

\[ y(u,v)= \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} x(m,n) \cos \left( \frac{2\pi}{2N} (2m+1)u \right) \cos \left( \frac{2\pi}{2N} (2n+1)v \right) \]

Where

\[ \alpha_u = \begin{cases} 1 & u = 0 \\ \frac{1}{\sqrt{2}} & u = 1,2,\ldots,N-1 \end{cases} \]

\[ \alpha_v = \begin{cases} 1 & v = 0 \\ \frac{1}{\sqrt{2}} & v = 1,2,\ldots,N-1 \end{cases} \]

The image is reconstructed by applying inverse DCT operation according to Eq. 2:

\[ x(m,n)= \sum_{u=0}^{N-1} \sum_{v=0}^{N-1} y(u,v) \cos \left( \frac{2\pi}{2N} (2m+1)u \right) \cos \left( \frac{2\pi}{2N} (2n+1)v \right) \]

The popular block-based DCT transform segments an image non-overlapping blocks and applies DCT to each block. This results in giving three frequency sub-bands: low frequency sub-band, mid-frequency sub-band and high frequency sub-band. DCT-based watermarking is based on two facts. The first fact is that much of the signal energy lies at low-frequencies sub-band which contains the most important visual parts of the image. The second fact is that high frequency components of the image are usually removed through compression and noise attacks. The watermark is therefore embedded by modifying the coefficients of the
middle frequency sub-band so that the visibility of the image will not be affected and the watermark will not be removed by compression [4].

For each set of images there are three results for every algorithm. The quality of recover image is measured by PSNR and normalization coefficient (NC) variation. Higher value of PSNR represents high quality of recover image due to small errors in image extraction algorithm. NC varies from 0 to 1 it is also the similarity measure between two images. If NC is closer to 1 it means that recovered image is very close to the original image. We have calculated PSNR1/PSNR2 that is PSNR between host image and watermarked image named as PSNR image and the PSNR between watermarked image and extracted watermarked image is PSNR2. Similar nomad is applicable to NC1 and NC2. We have applied our DCTDWTSDV noise algorithm on host1 image (fig 4(a)) to watermark the image wm2 (fig 4(d)). The image obtained after watermarking that is watermarked image is shown on fig 4(b). Then Gaussian image (fig 4(c)) attacks is apply on watermarked image and it is Dewater marked and its extracted watermarked image is shown in fig 4(e).

DWT-DCT-SVD Watermarking Scheme:
The description of DWT-DCT-SVD watermarking is given below:
step 1 : Obtain the DWT of the Host image by db2 wavelet
step 2 : Obtain DCT on Ih1 by applying IDWT of the LL component of the wavelet transform of host image.
step 3 : Apply SVD decomposition on the Ih1 to get U1,S1 and V1 components.
step 4 : Apply SVD decomposition of the watermark image W in U2,S2 and W2 components.
step 5 : Calculate Shw=S1+a*S2 where a<=1 (constant).
step 6 : Calculate Ihw=U1*Shw*V1
step 7 : Apply wavelet transform on Ihw to get LL2,Hl2,Lh2 and HH2 wavelet components.
step 8 : Obtain the water mark image as Iw=inverse wavelet of (LL,HL,LH,HH2).

The description of DWT-DCT-SVD dewatermarking is given below:
step 1 : Apply wavelet transform on watermarked image Iw to get LL,HL,LH and HH components
step 2 : Apply DCT on inverse wavelet transform on LL component obtained in previous step to get Ihm.
step 3 : Apply SVD decomposition of the Ihm to obtain UW,SW and VW components.
step 4 : Apply SVD decomposition of the watermark image W.
step 5 : Obtain Em=|SW-Swm|
step 6 : Obtain extracted watermark Ew =Uwm*Em*Vwm.

5. Result and Discussion:
We have applied three different algorithms for digital image watermarking and for each scheme there are three kinds of result as describe below.
1. Image watermarking/Dewater marking without any image attack.
2. Image watermarking/Dewater marking with Gaussian noise image attack.
3. Image watermarking/Dewater marking with salt and paper noise image attack.
We have applied our DCTDWT SVD salt noise algorithm on host image (fig 4(a)) to watermark the image wml (fig 4(c)). The image obtained after watermarking that is watermarked image is shown on fig 5 (a). Then Salt and paper image (fig 5(b)) attacks is apply on watermark image and it is Dewatermarked and its extracted watermarked image is shown in fig 5(d).
6. Conclusion:
In this paper results suggests that DC-SVD-DWT based watermarking scheme is giving best performance in the presence of recovery of watermark image used to indicates the text based data of biomedical images. The results are verified analytically in terms of PSNR and normalization coefficients and both are found high for novel DCT-DWT-SVD watermarking scheme. In future the work can be extended for considering other image attacks effect and code parameter optimization in terms of additional image attacks. Presently we have considered the algorithm robustness for salt and pepper noise and Gaussian noise. In future effects of compression, transformation and cropping can also be considered for demonstrating the performance of developed watermarking scheme.

References: