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Extracted Image Quality Improvement Algorithm Using Hybrid Digital Watermarking

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Abstract
The proposed model makes changes in existing algorithm by boosting alpha values in an algorithm involving use of hybrid watermarking techniques like Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), and Singular Value Decomposition (SVD) to enhance efficiency and accuracy in watermark embedding and extraction. As DC coefficients are perceptually most significant and more robust to many unintentional attacks (signal processing) and intentional attacks (unauthorized removal), in this paper we use existing algorithm, but we intend to make new algorithm that will be blind, which means cover object may not be present at receiver's end for extracting watermark. The second intension is to make the system more robust to almost all attacks including rotation attack, than the existing algorithm. Performance evaluation based on Peak Signal-to-Noise Ratio (PSNR) and Normalized Correlation (NC) demonstrates significant improvements in watermark quality and resilience against attacks. Identifying the gap to improve NC values, we modified the existing algorithm only in extraction process and because of new algorithm, NC values improved for many attacks including Rotation Attack. The measured PSNR and NC values are tabulated for all the 3 planes (RED, GREEN and BLUE) for 6 selected attacks and even without attack.
***Index Terms**– Digital Watermarking, Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD).*

INTRODUCTION

With the development of web communication and multimedia technology, more and more digital multimedia signals can be transmitted through Internet which in turn vulnerable to various attacks. Among today's information security techniques, multimedia watermarking techniques have been developed greatly and become a kind of powerful tool for protecting multimedia content. Watermarking is the process of embedding data into multimedia content such as an image, audio or video file for the purpose of copy right protection, ownership verification, broadcast monitoring, authentication etc. The important properties of watermarking algorithms include imperceptibility, robustness, security and watermark recovery with or without the original data [1][2]. To be robust, it is preferred to embed the watermark in perceptually most significant components, but this may affect the visual quality of the image and watermark may become visible. If perceptually insignificant coefficients are selected for embedding, then the watermark may be lost by common signal processing operations. Thus, determining the place of watermark is a conflict between robustness and fidelity and it is purely application dependent. Generally, information could be hidden either by directly modifying the intensity value of pixels or frequency coefficients of an image. The former technique is called spatial domain technique and later is called frequency domain technique. To obtain frequency components of an image, it needs to be transformed using any one of the transformation techniques such as Discrete Fourier Transformation (DFT), Discrete Cosine Transformation (DCT) [3]. Discrete wavelet Transformation (DWT)[4]. In transform domain casting of watermark can be done in full frequency band of an image or in specific frequency band such as in low frequency band or in high frequency band or in middle frequency band. In this paper we proposed a new robust watermarking algorithm that combines the features of discrete wavelet transform, singular value decomposition and discrete cosine transformation techniques. The advantages of the proposed method are its robustness and its capacity. Robustness is achieved through embedding of watermark in most significant coefficients (DC coefficients) and capacity is increased by using three channels (RGB) of color image. The proposed algorithm is tested against various signal processing operations and many attacks and found that the algorithm is robust. The robustness is tested by measuring the similarity of original and extracted watermarks which is more than 90 percent for all kinds of attacks except the rotation attack. The rest of the paper is organized as follows; Review of related works is given in section II. Preliminaries of DWT-DCT-SVD techniques are discussed in section III. Proposed algorithm is discussed in section IV. Results are elaborated in section V. Concluding remarks are given in section VI.

REVIEW OF RELATED WORKS

Review of literature survey has been conducted on discrete wavelet transformation (DWT), discrete cosine transform (DCT) combined with singular value decomposition (SVD) techniques for hiding information in digital color images. In [3] the image is divided into many block of size 8x8 and it is block transformed using DCT technique. These transformed blocks are randomly shuffled to decorrelate and to spread the watermark across the entire image. The mid band blocks are selected from the permuted blocks to embed watermark. This system is more robust than SVD based method. In [4] the cover is decomposed into four bands. The high frequency band is inverse transformed to obtain high frequency image and it is SVD decomposed to embed watermark by modifying high frequency components. Results show that the system is withstanding certain attacks including geometric attacks. In [5] Image is transformed by DWT technique to K level. The middle frequency band LH and HL are SVD transformed and watermark is hidden. Similarly in low frequency and high frequency band the watermark is embedded using distributed discrete wavelet transform method (DDWT). Both algorithms are tested against attacks ad proved that they are robust against cropping attacks. For attacks such as Gaussian Noise, contrast adjustment, sharpness, histogram equalization, and rotation the proposed scheme is robust by exploiting the advantage of the SVD watermarking technique. In [6], three level decomposition of DWT is applied on image to get ten bands of frequencies. All ten bands of frequency coefficients are SVD transformed to embed watermark. A new watermarking scheme for images based on Human Visual System (HVS) and Singular Value Decomposition (SVD) in the wavelet domain is discussed. Experimental results show its better performance for compression, cropping and scaling attack. In [7] two level decomposition of DWT is applied to transform an image into bands of different frequency and a particular band is selected and converted into blocks of size 4x4 for embedding data. Each of those the blocks are SVD transformed and watermark is hidden into diagonal matrix of every block. The similarity between the original watermark and the extracted watermark from the attacked image is measured using the correlation factor NC. The algorithm shows that when DWT is combined with SVD technique the watermarking algorithm outperforms than the conventional DWT algorithm with respect to robustness against Gaussian noise, compression and cropping attacks. In [8] a new algorithm is proposed for embedding watermark in color images. The blue color channel of the image is decomposed to obtain four frequency bands and the selected band is SVD transformed to to hide watermark. This scheme performs well for JPEG compression attacks. In [9] the new non-invertible method is proposed by combining DWT and SVD technique. The performance evaluation shows that the algorithm is robust against attacks such as cropping, Gaussian noise, JPEG compression. In [10] human visual system is exploited while embedding watermark. In [11], DWT and SVD techniques are combined to embed watermark in YUV channel. YUV channels are decomposed by applying wavelet transformation technique followed by SVD technique. Since the watermark is hidden in full band of YUV channel, the DSFW is robust to many signal processing attacks. In [12], the DWT technique is applied to decompose input image and LL band is converted into many blocks for DCT transformation. Only DC coefficients are selected, and a new matrix is formed, this new matrix is SVD decomposed for watermark embedding. In [13], the paper proposed a digital watermarking hybrid algorithm based on color images. The specific process is to adopt the idea of multi- algorithm layered embedding, choose the algorithm based on discrete cosine transform (DCT) algorithm, discrete wavelet transform singular value decomposition (DWT_SVD) algorithm, and hologram algorithm, these three algorithms with robust complementary functions, then embed the same watermark image into the color image R, G and B layers to complete the watermark embedding. In [14], a novel watermarking algorithm using two layers of transform, first layer is Complex Wavelet Transform and the second one is the singular value decomposition (SVD) is proposed. In [15], there is a chapter on Watermarking written by authors in Wiley online Library about different watermarking applications, requirements and methods. In [16], the authors present a comprehensive review of watermarking techniques in deep-learning environments. They start with basic concepts of traditional and learning-based digital watermarking, they later review the popular deep-learning model-based digital watermarking methods; then, they summarize and compare the most recent contribution in the literature. Finally, they highlight obfuscation challenges and further research directions. In [17], the paper surveys soft computing-based image watermarking for several applications. The paper first elaborate on novel applications, watermark characteristics and different kinds of watermarking systems. Then, soft computing based watermarking approaches providing robustness, imperceptibility and good embedding capacity are compared systematically. Furthermore, major issues and potential solutions for soft computing-based watermarking are also discussed to encourage further research in this area. Thus, this survey paper is helpful for researchers to implement an optimized watermarking scheme for several applications. In paper [18], deep learning-based methods which are popular in multimedia analysis tasks, including classification, detection, segmentation, and so on are discussed . In addition to conventional applications, their model can be widely used for cover communication, i.e., information hiding. The paper presents a review of deep learning-based covert communication scheme for protecting digital contents, devices, and models. In particular, they discuss the background knowledge, current applications, and constraints of existing deep learning-based information hiding schemes, identify recent challenges, and highlight possible research directions. In [19], the authors states that extensive research on watermarking has been conducted, including a hybrid DWT-DCT-SVD approach. Several studies have found weaknesses in the message insertion process, for example, the time required to insert a watermark image is relatively long, particularly for large images. To address the problem of long message insertion times, their study applies a compression process to the original image before the watermark image insertion process. The original image to be inserted into the watermark image is compressed using the run-length encoding (RLE) algorithm. The results of RLE compression demonstrate that image file size is reduced significantly, which optimizes the watermarking process. In [20], the paper presents lifting wavelet transform (LWT) and discrete cosine transform (DCT) based robust watermarking approach for tele-health applications. For identity authentication, signature watermark' of size '64 × 64' and 'patient report' of size '80' characters are hiding into the host medical image. Further, the signature watermark is encrypted by message-digest (MD5) and 'patient report' is encoded by BCH error correcting code before embedding into the host image. Experimental demonstrations indicate that the method provides sufficient robustness and security against various attacks without significant distortion between cover and watermarked image. In [21], the authors developed a data hiding scheme, which can guarantee the security of the COVID-19 images. Combination of RDWT-RSVD is used to perform imperceptible marking of logo mark within the carrier media. The principal component of mark image is hidden in the host image, which solves the FPP issue. PCA is utilized to determine the normalized principal component for embedding purposes. Based on the review performed many works are existing for embedding watermark by combining DWT and SVD techniques for intensity images. In the proposed work the watermark is embedded in the DC components of transformed color image. To increase the robustness, the low frequency band can be selected. But to increase the capacity of the watermark full band can also be used. The selected band is divided into block of size 2x2 which in turn DCT transformed to obtain only DC coefficients. These DC coefficients are SVD transformed to embed watermark in singular values.

III Image Transformation Techniques

A. Discrete Cosine Transform

The Discrete Cosine Transform allows an image to be broken up into different frequency bands, making it much easier to embed watermarking information into the middle frequency bands of an image. The middle frequency bands are chosen such that they have minimized they avoid the most visual important parts of the image (low frequency) without over-exposing themselves to removal through compression and noise attacks. The transformed matrix consists of both AC and DC coefficients. If the DCT technique is applied on block of size NxN then it is called block DCT. In DCT transformed block the left top corner element is called as DC coefficient which is perceptually significant and the remaining coefficients are called AC coefficients which are perceptually insignificant. These coefficients are zigzag scanned to obtain frequency components of an image in the decreasing order. Techniques to modify DC and AC components to embed watermark are as proposed by [3] and [11]

Advantages:

1) DCT domain watermarking is comparatively much better than the spatial domain encoding since DCT domain watermarking can survive against the attacks such as noising, compression, sharpening, and filtering.

2) It uses JPEG compression method to apply DCT watermarking as a parameter. One may use different parameters related to image processing, and these parameters might provide equal or even stronger robustness against various attacks based on image processing.

3) Discrete cosine transform (DCT), where pseudorandom sequences, such as M sequences, are added to the DCT at the middle frequencies as signatures.

B. Discrete Wavelet Transform

The basic idea in the Discrete Wavelet Transform for a one-dimensional signal is the following. A signal is split into two parts, usually high frequencies and low frequencies. The edge components of the signal are largely to the high frequency part. The low frequency part is split again into two parts of high and low frequencies. This process is continued an arbitrary number of times, which is usually determined by the application at hand.DWT is a transformation technique used to represent an image in a new time and frequency scale by decomposing the input image into low frequency, middle and high frequency bands. The value of low frequency band is the averaging value of the filter whereas the high frequency coefficients are wavelet coefficients or detail values. [4].DWT can be used to decompose images as a multistage transform. In the first stage, an image is decomposed into four sub bands LL1, HL1, LH1, and HH1, where HL1, LH1, and HH1 represent the finest scale wavelet coefficients, while LL1 stands for the coarse level coefficients, i.e., the approximation image.

Advantages:

1) The watermarking method has multi resolution characteristics and is hierarchical. It is usually true that the human eyes are not sensitive to the small changes in edges and textures of an image but are very sensitive to the small changes in the smooth parts of an image. With the DWT, the edges and textures are usually to the high frequency sub bands, such as HH, LH, HL, LL etc. Large frequencies in these bands usually indicate edges in an image.
2) The watermarking method robust to wavelet transform based image compressions, such as the embedded zero-tree wavelet (EZW) image compression scheme, and as well as to other common image distortions, such as additive noise, rescaling/stretching, and half toning. This is an advantage over DCT.
3) DWT separates an image into lower resolution approximation image (LL) as well as horizontal (HL), vertical (LH) and diagonal (HH) detail components.
The whole process then can be repeated to compute multiple scale wavelet de- compositions.

C. Singular Value Decomposition

SVD is a mathematical tool used to analyze matrices. In SVD, a given matrix A is decomposed into three matrices such that, A=USVT where U and V are orthogonal matrices and UTU=I, VTV=I, I is an identity matrix. The diagonal entries of S are called the singular values of A, the columns of U are called the left singular vectors of A, and the columns of V are called the right singular vectors of A. This decomposition is known as the singular value decomposition (SVD) of matrix A. Usually, watermark is embedded in the singular matrix, and if the watermark is embedded in the orthogonal matrices of SVD then the perceptibility of host image is improved it is not robust to many attacks because the matrix elements of orthogonal matrices are very small. The three main properties of SVD from the view point of image processing applications are [11].

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1. The singular values of an image have very good stability, that is, when a small perturbation is added to an image, its singular values do not change significantly.

2. Each Singular value specifies the luminance of an image layer while the corresponding pair of singular vectors specifies the geometry of the image.

3. Singular values represent intrinsic algebraic properties.

Advantages:

1)SVD is a stable and effective method to split the system into a set of linearly independent components, each of them is carrying own data (information) to contribute to systems. Thus, both the rank of the problem and subspace orientation can be determined.

2) It provides a good compression ratio, and that can be well adapted to the statistical variation of the image.

IV ALGORITHM FOR EMBEDDING AND EXTRACTING WATERMARK

Proposed algorithm combines the properties of DWT, DCT and SVD techniques to increase the robustness and capacity of the algorithm by selecting significant coefficients and number of color channels. The procedure for embedding and extracting the watermark is given below.

A.WATERMARK EMBEDDING ALGORITHM

Existing algorithm combines the properties of DWT, DCT and SVD techniques to increase the robustness and capacity of the algorithm by selecting significant coefficients. These properties are combined as proposed in 'DC coefficient based watermarking technique for color Images using Singular Value decomposition' by
V.Santhi, Arunkumar Thangavelu[2]. As we have only made changes in Extraction Process, the embedding process remains same as [1] and [2].

B. Proposed Watermark Extraction Algorithm

1. Convert the watermarked image into RGB color spaces.
2. Apply DWT to decompose the respective color space of a cover image in which watermark is hidden.

$[LL, LH, HL, HH]$
$= 2dw('colorspace','filtername')$

3. Divide middle frequency band into smaller 4x4 blocks and apply DCT to each block, B*.
4. Extract the DC coefficients σij from every DCT transformed blocks and construct a new matrix C, which could be decomposed by SVD technique,

C=U* S* V*T

5. Extract the singular values from C matrix, then compare the difference between the watermarked singular values and host image singular values,

S3=α* S*

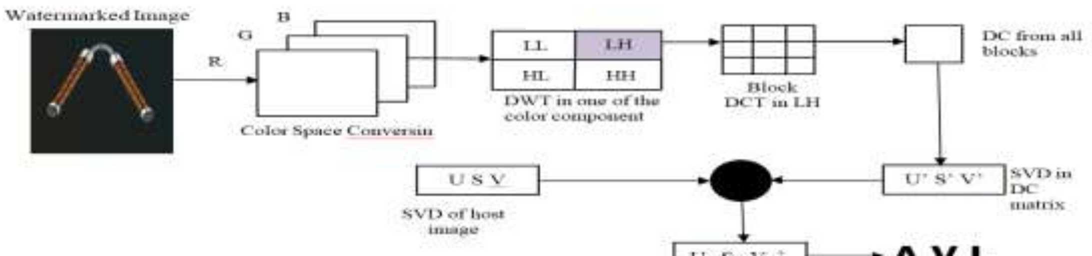
6. Combine the obtained singular values with the orthogonal matrices of watermark,

W* = Uw S3 VwT

7. Repeat the same procedure to extract the watermark from other bands.

In the proposed method, to extract the watermark from all frequency bands, it uses original cover image. So, this algorithm is can be classified as non-blind watermarking techni ove embedding and extraction algorithm can be tested for all the three color spaces of (RGB) an image. The embedding of proposed algorithm is shown in Fig. 2. **Fig. 2**

Fig. 2 Watermark embedding process [2]



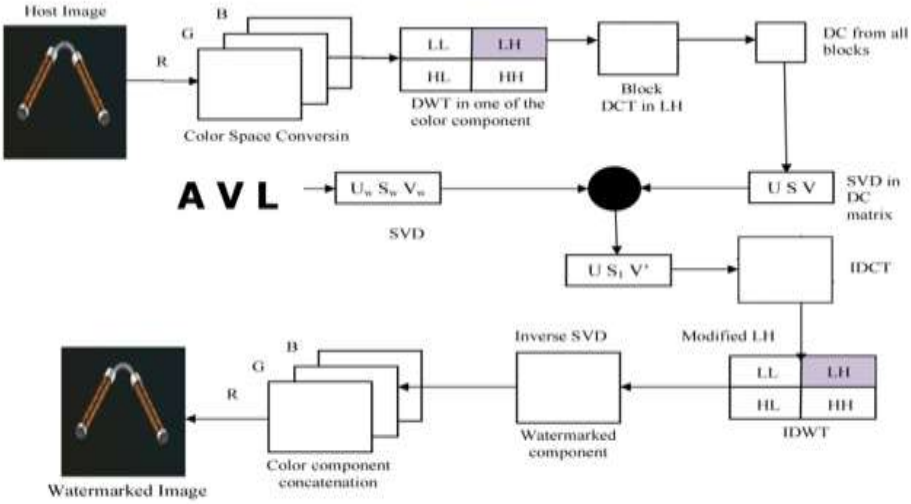


Fig. 3 Watermark extraction process [2]

In equation 5 of watermark extraction algorithm there is a formula S3=α* S*, which is different from existing algorithm [1] and [2] which had formula as S3= (S^*- S)/α.In this α is kept as 0.5. For all possible values of NC, watermark embedding is performed in all the 3 planes, i.e R-plane,G-plane and B-plane and in all 4 frequency bands like LL, LH, HL and HH. The results demonstrated tables of PSNR values and NC values for all 3 planes and all 4 frequency bands, also for six attacks and even in the absence of attack, providing deeper insights into watermark robustness. These findings emphasize the need for adaptive watermarking frameworks that adjust dynamically to varying attack scenarios, ensuring higher security reliability in digital watermarking systems.

V. PERFORMANCE EVALUATION: In this proposed algorithm the Nanchak image of size 512x512 is taken as test image and the size of watermark considered is 64x64. Selected embedding intensity value is 0.1 for all frequency bands. Based on particular application the frequency band and the color channel can be selected. If the size of the watermark is small then any one of the color channel can be selected and application decides the frequency band. This proposed algorithm is tested by embedding watermark in all frequency band of red , green and blue color space.

The original image, watermark and watermarked image are shown in Fig 4(a), 4(b) and 4(c) respectively. Similarly the extracted watermarks are shown in Fig.5.

Fig 4:(a)Host image (b) watermark (c)Watermarked image

Fig 5: Extracted watermark from all frequencies.

5.1 The tables shown below display the experimental results of PSNR while embedding watermark and NC while extracting watermark.

PSNR values in RED

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Channel	Exist	Prop
LL	21.6225	21.6225
LH	33.5315	33.5315
HL	33.6666	33.6666
HH	35.0434	35.0434

NC values in RED

Attacks	LL		LH		HL		HH	
	Exist	Prop	Exist	Prop	Exist	Prop	Exist	Prop
Without Attack	0.8742	0.9933	0.9978	0.9936	0.9973	0.9933	0.9963	0.9960
Salt and Pepper	0.9133	0.9932	0.7323	0.9388	0.7542	0.9429	0.7493	0.9322
Rotation	0.4689	0.9942	0.1448	0.8833	0.5364	0.9435	0.1877	0.7903
Sharpening	0.8997	0.9929	0.9920	0.9939	0.9938	0.9936	0.9900	0.9937
Gaussian Blurr	0.8709	0.9942	0.0842	0.8962	0.0969	0.9178	0.0543	0.8048
Horizontal Line	0.9022	0.9932	0.9922	0.9936	0.9975	0.9933	0.9963	0.9960
Vertical Line	0.9013	0.9933	0.9977	0.9936	0.9949	0.9930	0.9963	0.9961

PSNR values in GREEN

Channel	Exist	Prop
LL	21.6225	21.6225
LH	33.5315	33.5315
HL	33.6666	33.6666
HH	35.0434	35.0434

NC values in GREEN

Attacks(Green)	LL		LH		HL		HH	
	Exist	Prop	Exist	Prop	Exist	Prop	Exist	Prop

Without Attack	0.9048	0.9927	0.9982	0.9938	0.9986	0.9935	0.9971	0.9964
Salt and Pepper	0.9087	0.9927	0.7317	0.9370	0.7470	0.9435	0.7427	0.9306
Rotation	0.0830	0.9941	0.1520	0.8850	0.4604	0.9427	0.1821	0.8024
Sharpening	0.8671	0.9924	0.9940	0.9942	0.9953	0.9936	0.9914	0.9941
Gaussian Blurr	0.7225	0.9941	0.0974	0.8978	0.0804	0.9194	0.0518	0.7616
Horizontal Line	0.9086	0.9928	0.9947	0.9934	0.9987	0.9935	0.9971	0.9964
Vertical Line	0.9072	0.9928	0.9981	0.9938	0.9970	0.9932	0.9971	0.9964

PSNR values in BLUE

Channel	Exist	Prop
LL	21.6225	21.6225
LH	33.5315	33.5315
HL	33.6666	33.6666
HH	35.0434	35.0434

NC values in BLUE

Attacks(Blue)	LL		LH		HL		HH	
	Exist	Prop	Exist	Prop	Exist	Prop	Exist	Prop
Without Attack	0.9947	0.9926	0.9986	0.9941	0.9991	0.9936	0.9967	0.9965
Salt and Pepper	0.8675	0.9924	0.7399	0.9365	0.7417	0.9365	0.7520	0.9295
Rotation	0.0765	0.9939	0.1736	0.8877	0.4511	0.9426	0.2055	0.7818
Sharpening	0.8975	0.9921	0.9956	0.9941	0.9969	0.9935	0.9909	0.9941
Gaussian Blurr	0.4650	0.9944	0.1183	0.9006	0.0778	0.9205	0.0523	0.7814
Horizontal Line	0.9953	0.9926	0.9967	0.9936	0.9991	0.9936	0.9967	0.9965
Vertical Line	0.9951	0.9926	0.99852	0.9940	0.9977	0.9935	0.9967	0.9965

CONCLUSION

In the proposed algorithm the features of DWT-DCT-SVD techniques are combined. Embedding of watermark is done only in DC components of frequency bands to increase the robustness. The results of the proposed algorithm have higher NC values when compared with existing algorithm[1][2]. Existing algorithm[1] [2]was not robust for Rotation Attack, but proposed algorithm is far better than existing algorithm for all attacks including rotation attack. Algorithm is tested against many attacks and found to be robust. So that the new system can be used in applications such as copyright protection and ownership verification.
Existing Algorithm [1][2] is non-blind, which means cover object should be present at the receiver end, using which watermark image is extracted. The proposed algorithm works even if cover object is not available at receiver end.

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