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Robust Digital Image Watermarking for Copyright Protection with SVD-DWT-DCT and Kalman Filtering

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Abstract -Information security is a widely used concept in internet technology. Digital image Watermarking is a way to achieve information security. Digital Image Watermarking hides information in the original image without affecting much quality of the image. Copyright protection or rightful ownership is the main purpose of performing digital image watermarking. Watermarking techniques mainly focus on the robustness of image which simply means to improve imperceptibility. In this paper, a digital image watermarking technique SVD-DWT-DCT with Kalman Filtering has been proposed that works in frequency. Experimental evaluation of the technique on the basis of PSNR, MSE has shown that the SVD-DWT-DCT with Kalman Filtering gives better results in contrast to SVD-DWT-DCT technique.

Keywords: SVD, DWT, DCT, Kalman Filtering, PSNR, MSE.

1. INTRODUCTION

Digital Watermarking is a technique which is used to embed useful information into a digital object. The useful information is called a Watermark. Watermark can be visible and invisible. Visible watermark is the data that can be easily seen by the human eye after embedding. Invisible watermark is the hidden data or information which when embedded into the digital object cannot be identified by the human eye. A watermark can be embedded into a multimedia object by an authorized person and can be detected by another authorized person in an invisible watermarking process. Various mechanisms are there which are used to embed watermark into multimedia object say image, audio, video etc. But all these mechanisms should have at least two properties of invisible watermarking: imperceptibility and robustness. There are two domains in which the watermarking process is being classified: Spatial Domain and Frequency domain. In spatial domain watermarking techniques, operations are directly performed on pixels. Least significant bits and texture mapping are the two mostly used techniques of spatial domain watermarking. But these techniques do not meet the requirement of robustness. The watermarking in frequency and transform domain is much secure from unauthorized attacks [1]. Discrete Cosine Transform, Discrete Wavelet Transform, Discrete Fourier Transform and Singular Value Decomposition are the mostly used watermarking mechanisms in frequency domain. In this paper, Singular value decomposition- Discrete Cosine Transform - Discrete Wavelet Transform is used as a watermarking mechanism. The technique is enhanced using the LH band and Kalman Filter. The performance of both the traditional SVD-DCT-DWT and the enhanced SVD-DCT-DWT technique is measured for robustness and imperceptibility through two performance metrics: peak signal to noise ratio and mean square error.

1.1 Singular Value Decomposition:

Singular Value Decomposition is a linear algebraic algorithm. The significant amount of information is preserved by SVD subspace and that's why it is used for solving the false positive problem. The principle components of watermark are inserted into the singular values of the original image. It makes impossible for the unauthorized author to know the exact principle components and singular values of the image. The other key point of SVD based image watermarking is the stability property of the singular value matrix. A digital Image X of size M×N, with M ≥ N, can be represented by its SVD as follows:

$$X = USV^T \tag{1}$$

$$U = [U1, U2\ldots\ldots Um], \tag{2}$$

$$V = [V1, V2\ldots\ldots Vn], \tag{3}$$

$$S = \begin{bmatrix} \sigma_1 & & & \\ & \sigma_2 & & \\ & & 0 & \\ & & & \sigma_n \end{bmatrix} \quad (4)$$

where U is an M×M matrix, V is an N×N matrix, and S is an M×N matrix with the diagonal elements representing the singular values of X. T denotes the transpose of the matrix. The columns of the orthogonal matrix U are called left singular vectors and the columns of the orthogonal matrix V are called right singular vectors. For solving the ownership problem, relevant scaling factor is used which can preserve the robustness of the watermark. For performing SVD based image watermarking, two images, original image and watermark image, are required. If colored watermark image is there then it is changed into gray scale image first and then the procedure is followed [2] [3].

1.2. Discrete Wavelet Frequency:

DWT is a frequency domain technique which shows robust results. DWT consists of filters which divides an image into four multiresolution subbands. These subbands are denoted by LL, LH, HL and HH. LL band describes the coarse level coefficients of the image and the other three bands describe the finest scale of wavelet coefficients. LL band of the DWT has the greatest magnitude. The advantage of greatest magnitude and high resolution is that it indicates the edges and patterns of an image. DWT technique is the most commonly used technique in image watermarking, audio and video watermarking [3][4].

1.3. Discrete Cosine Frequency:

DCT separates the image into three frequency coefficients. These frequency coefficients may vary through low, high and middle frequency coefficients. For robust results, the embedding is performed in the middle frequency. The visibility of the image is not affected if the image is embedded in the middle frequency components of the discrete cosine frequency. Also DCT describe the location of the image in which the watermark is to be embedded. Middle frequency of the DCT usually gives robust and imperceptible results [4].

1.4. Kalman Filtering:

Kalman Filter is a filter which is based upon digital signal processing. The various types of estimates can be given through this filter. The past, present and future estimates or states of a system can be measured through this filter. This filter has been used in the enhanced technique present in this paper. It minimizes the noise and improves the robustness of the image. The main purpose of using Kalman filter is to minimize the MSE and increase the PSNR value [5][6].

1.5. Performance parameters:

The quality of watermarked image is measured with two main performance metrics: PSNR (Peak Signal to noise ratio) and MSE (Mean Square Error). The MSE is calculated as follows:

$$MSE = \sum_{M,N} \frac{[c(m,n) - e(m,n)]^2}{M * N} \quad (5)$$

where M, N are the number of rows and columns in input image, *c(m,n)* and *e(m,n)* are the watermarked image and the original image respectively.
The value of PSNR is obtained as:

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{L * L}{\mathrm{MSE}}\right) \quad (6)$$

where L is the maximum fluctuation in input image data type. In this experiment L=255 is taken. It is expressed in terms of logarithmic decibel scale [7].

2 RELATED WORK

Nikolaidis, N. and Pitas, I. describes the various data hiding techniques which are used for the purpose of copyright protection. Authors described the various spatial domain watermarking techniques that work with pixel values of the image directly. They concluded that the frequency domain techniques give better and robust results as compared to the spatial domain watermarking techniques [8]. Emir Ganic, et al. presented a hybrid scheme based on DWT and SVD. The original image is decomposed into four subbands by applying DWT technique first. Singular value decomposition is performed on each of the decomposed band by modifying the singular values. The modifications develop the development of the watermarking scheme by displaying robust results on wide range of attacks [9].

K. S. Rawat, et al. described various watermarking methods for authorization again piracy of the images. The features of the watermark, classification and applications of the watermark are also described in the paper. For image authentication and protection of attacks, watermarking technique is the best technique. The results proved that increase in robustness may decrease the imperceptibility [10]. Navnidhi Chaturvedi N., et al. compared two popular watermarking techniques. Discrete wavelet transform is compared with discrete wavelet and cosine transform and the results are obtained on the basis of PSNR and MSE values. DWT performed 2 level decomposition of the original image. The results have proved that DWT-DCT method shows better results than DWT technique [11].

HB Kekre, et al. proposed a technique using Discrete Wavelet Transform and Singular Value Decomposition. This technique helped in increasing the robustness of the watermarked image. The results conclude that the use of this technique improves the overall performance of the watermarked image as compared to haar wavelet functions [12]. Amit Kumar Singh, et al. proposed an algorithm for digital watermarking based on discrete wavelet transforms (DWT), discrete cosine transforms (DCT), and singular value decomposition (SVD). This hybrid technique is tested against various attacks like contrast adjustment, histogram equalization, average filter and linear filtering. Results have shown that this method needs less SVD computation than other methods and the results are robust against various attacks [13].

In this paper, the main focus is on the quality of the watermarked image by using Kalman Filtering with SVD-DWT-DCT. The performance of this technique is measured through Mean Square Error and Peak Signal to Noise Ratio. Both these quality factors tell about the obtained quality of the watermarked image.

3. PROPOSED MODELLING

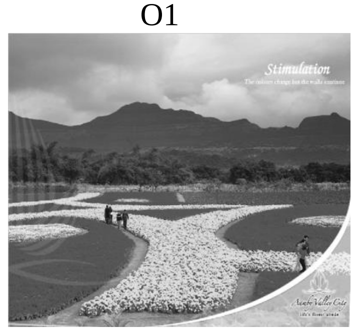
In Enhanced SVD-DWT-DCT using Kalman Filtering, two images are taken for the experiment-Original image and Watermark image. Firstly, SVD is applied on the original image as well as the watermark image. It divides the image into three parts. Horizontal part is denoted by U component, vertical part is denoted by V component and diagonal part is denoted by S component. An output image is obtained by replacing the diagonal component of the watermark image with the diagonal component of the original image. DWT is applied on the SVD based image. LH band is selected from all the four bands of the DWT image. DCT is applied on the DWT based image. An image is obtained which is called watermarked image. The quality of the watermarked image is measured through PSNR and MSE parameters. The Kalman Filtering is performed on the obtained watermarked image. The quality of the image is again measured which gives better results that only SVD-DWT-DCT technique. Experiments have shown that the Enhanced SVD-DWT-DCT with Kalman Filtering technique gives better results than SVD-DWT-DCT technique.

4. RESULTS AND DISCUSSIONS

In the experiment, the three techniques are applied on different images. The brief introduction of the above techniques is given in Introduction section. Different test images are used for the experiment. These images are shown by Figure 3.1 and 3.2.

O1

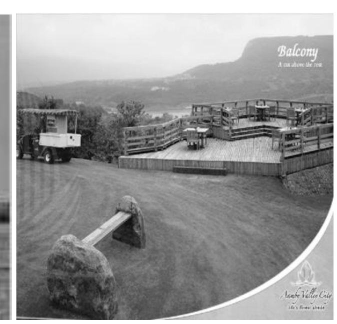
O2



O3

Figure 3.1 Test Images used for experimentation. Original Images (O1, O2, O3).

W1

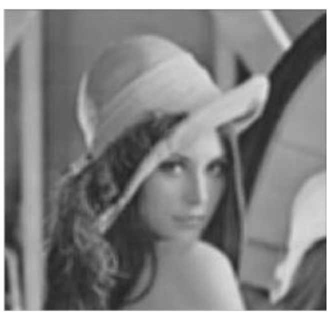


W2

W3

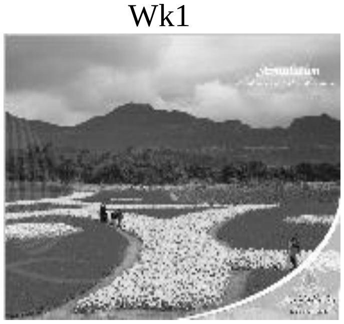
Figure 3.2 Test Images used for experimentation. (b) Watermark Images (W1, W2, W3)

The images in Figure 3.1 are the original images which are denoted by O series in the tables. The images in Figure 3.1 are the watermark images or the useful information denoted by W series which is to be embedded in the original image. A third image is obtained by the combination of the two images, called watermarked image Figure 3.3 shows the watermarked images obtained by performing SVD-DWT-DCT technique on images in Figure 3.1 using watermarks shown in Figure 3.2. The results are evaluated on the basis of performance parameters: PSNR and MSE.



Wk1

Wk2



Wk3

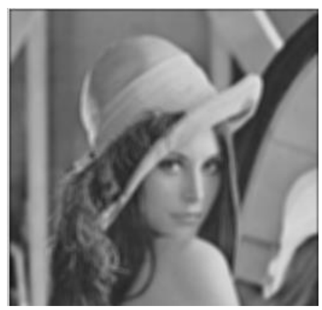
Fig 3.3 SVD-DWT-DCT based Watermarked Images

PSNR and MSE values obtained for watermarked images shown in Figure 3.3 are as shown in Table 1.

Table 1. Performance evaluation of PSNR and MSE after applying SVD-DWT-DCT technique.

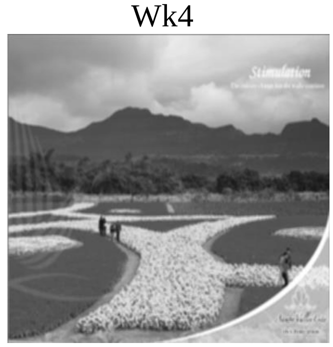
Original Image	**Watermark Image**	**PSNR**	**MSE**
O1	W1	24.17	251.00
O2	W2	24.47	250.95
O3	W3	24.10	251.30

In the second experiment, after applying SVD on the original as well as on watermark image, DWT is applied on the output image. LH band of DWT is taken as input to the DCT technique. After applying SVD-DWT-DCT, the watermarked image is filtered through Kalman Filter. Figure 3.4 shows the watermarked images obtained by applying the SVD-DWT-DCT technique with Kalman Filtering.



Wk4

Wk5



Wk6

Fig 3.4 SVD-DWT-DCT with Kalman Filtering based Watermarked Images

The PSNR and MSE values for the watermarked images of Figure 3.4 are shown in Table 2. PSNR values show a high increase with the usage of Kalman filter, whereas MSE is decreased.

Table 2: Performance evaluation of PSNR and MSE after applying SVD-DWT-DCT technique with Kalman Filtering.

Original Image	**Watermark Image**	**PSNR**	**MSE**
O1	W1	30.26	61.72
O2	W2	30.54	57.27
O3	W3	30.34	60.66

Both the SVD-DWT-DCT and enhanced SVD-DWT-DCT using Kalman Filtering techniques are compared. It is seen that PSNR is highly increased with Kalman Filtering. The image quality is dependent on the PSNR value. So it is clear that watermarked image become more imperceptible with Kalman Filtering. MSE of the watermarked image is also decreased in the enhanced technique.

5. CONCLUSION

The SVD-DWT-DCT technique is a hybrid technique that fulfils the main motives of the digital image processing. The two motives are: robustness and the imperceptibility of the watermarked image. These describe the quality of the watermarked image and helps in maintaining the secrecy of the digital media. The authorized way to perform digital image watermarking is attained by obtaining acceptable values of the performance metrics. By using SVD-DWT-DCT with Kalman Filtering, acceptable values of the PSNR and MSE are achieved and the watermarked image is highly robust which show that this technique is better than the traditional hybrid technique.

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