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Research Article

DCT-PCA Based Watermarking on E-governance Documents

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Abstract: In this study an efficient copyright protection scheme for e-governance documents has been proposed. The proposed method uses Discrete Cosine Transform (DCT) and Principal Component Analysis (PCA) to watermark the digital content. Experimental results show that the proposed method offers high imperceptibility and also the watermark is extracted perfectly.

Keywords: DCT and PCA, digital watermarking, e-governance documents

INTRODUCTION

Nowadays different government organizations have taken initiative to successfully implement E-Governance services among its citizens. Successful e-governance implementation requires all digital documents issued by the government is protected from illegal attacks attempting to modify the original contents. Data copying and back up are easier in the world wide web and multimedia. Because of such open access, copyright protection and authentication gradually lose their security.

E-Government can be visualized as utilization of information and communication technologies for the service of citizens, businesses and other areas of Government. Procurement of products in government departments is generally treated as the most sensitive activities which lack transparency and accountability. The copyright protection of E-Governance document is an important legal issue (Jobin and Varghese, 2012; Xiaowei, 2008). The most promising method seems to be the watermarking process where the original data is marked with secret information hidden in an imperceptible manner. In this study, a new watermarking method is developed via which can support privacy, integrity and authentication related issues of digital documents and give confidence to the user of the document that the transmission process is secure.

A digital watermark is a kind of marker covertly embedded in a noise-tolerant signal such as audio or image data. Watermarking is very similar to steganography in a number of respects. Both pursue to embed information inside a cover message with little to no degradation of the cover-object. Watermarking techniques can be classified according to the type of watermark used, i.e., watermark may be a visually recognizable logo or a sequence of random numbers.

Hiding information can be done in two ways, viz. Spatial domain technique (Da and Guo, 2009) and Transform domain technique (Bhatnagar and Raman, 2009; Chih-Chin and Cheng-Chih, 2010; Chuan-Fu and Wen-Shyong, 2000; Maheswari and Rameshwaran, 2012; Yassin *et al*., 2012; Reena and Saurabh, 2010; Lin *et al*., 2010). In Spatial domain technique (Da and Guo, 2009), pixel value is modified directly to embed the secret information. In Transform domain technique, Original image is transformed into transform coefficients by using various popular transforms like DCT (Chuan-Fu and Wen-Shyong, 2000; Hernandez *et al*., 2000; Reena and Saurabh, 2010; Lin *et al*., 2010) DFT (Solachidis and Pitas, 2001) and DWT (Bhatnagar and Raman, 2009; Chih-Chin and Cheng-Chih, 2010; Maheswari and Rameshwaran, 2012; Yassin *et al*., 2012; Vundela and Sourirajan, 2013) etc. Then, Transform coefficients are modified to embed the secret information. Transform domain offers very high robustness against compression such as JPEG (Subramanyam and Emmanuel, 2012), scaling, rotation, cropping, row and column removal, addition of noise, filtering, cryptographic and statistical attacks as well as insertion of other watermarks.

Robustness, imperceptibility and capacity are the three conflicting requirements of digital watermarking. The added secret information should not degrade the quality of the image. At the same time, it should not be removed by any attacks. Blind watermarking technique is necessary since sometimes it is not easy to obtain the

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original image or original watermark during extraction; also, a lot of space is needed for storing the original image and original watermark.

DCT is a very popular technique in image transform (Chuan-Fu and Wen-Shyong, 2000; Hernandez *et al*., 2000; Reena and Saurabh, 2010; Lin *et al*., 2010), especially in watermarking of images. Various watermarking methods are proposed in DCT domain. Principal Component Analysis (Karhunen-Loeve or Hotelling transform) -PCA belongs to linear transform based on the statistical techniques (Chih-Chin and Cheng-Chih, 2010; Khalilian and Bajic, 2013; Yassin *et al*., 2012). This method provides a powerful tool for data analysis and pattern recognition which is often used in signal and image processing as a technique for data compression, data dimension reduction or their de-correlation as well. There are various algorithms based on multivariate analysis or neural networks that can perform PCA on a given data set. In this study, we propose a DCT based watermarking scheme combined with PCA.

DISCRTE COSINE TRANSFORM AND PRINCIPAL COMPONENT ANALYSIS

Discrete Cosine Transform (DCT) is a sum of cosine functions oscillating at different frequencies. It is similar to the Discrete Fourier Transform (DFT) (Solachidis and Pitas, 2001) but using only real numbers. DCT is an orthogonal transform, is very widely used in image compression. Type-2 DCT transforms a block of image of size N×N having pixels (n_1, n_2) into a transform array of coefficients S (k_1, k_2), described by the Eq. (1):

$$s(k_1,k_2)=\sqrt{\frac{4}{N2}}C(k_1,k_2)\sum_{n=0}^{N-1}\sum_{n=0}^{N-1}\cos\left(\frac{\pi(2n_1+1)k_1}{2N}\right)\cos\left(\frac{\pi(2n_2+1)k_2}{2N}\right) \quad (1)$$

where, k_1, k_2, n_1, n_2 = 0, 1,.......N-1 and:

$$C(k)=\left\{\frac{1}{\sqrt{2}}\right. \text{ for k = 0}$$

$$C(k)=1 \text{ otherwise}$$

The transformed array S (k_1, k_2) obtained through Eq. (1) is also the same size of original image block *N*×*N*. It should be noted here, that the transform-domain indices k_1 and k_2 indicate the spatial frequencies in the directions of n_1 and n_2, respectively. $k_1 = k_2 = 0$ corresponds to the average or DC component and the remaining coefficients are AC components, correspond to higher spatial frequencies. For most images, signal energy lies at low frequencies; these appear in the upper left corner of the DCT (Reena and Saurabh, 2010; Lin *et al*., 2010).

DCT is having higher energy compaction capability. The DCT basis images can be computed using the transformation kernel, which is the same for both forward DCT and Inverse Discrete Cosine Transformation (IDCT) and is given by the Eq. (2):

$$g(n_1,n_2,k_1,k_2)=h(n_1,n_2,k_1,k_2) \\ =c(k_1)c(k_2)\cos\left(\frac{\pi(2n_1+1)k_1}{2N}\right)\cos\left(\frac{\pi(2n_2+1)k_2}{2N}\right) \quad (2)$$

Principal component analysis is a transform, for a given set of 'n' input vectors (variables) with the same length k formed in one dimensional vector $x = [x_1, x_2, \ldots. x_n]^T$ into a vector *y* according to the Eq. (3):

$$y = A(x - m_x) \quad (3)$$

Each row of the vector *x* consists of k values belonging to one input. Vector m_x in Eq. (3) is the vector of mean values of all input variables defined by the following relation:

$$m_x = \frac{1}{K}\sum_{k=1}^{K} x_k \quad (4)$$

Matrix A in Eq. (3) is determined by the covariance matrix C_x. Rows in the matrix A are formed from the eigenvectors of C_x according to corresponding eigen values in descending order. The evaluation of the C_x matrix is possible according to the relation (5):

$$C_x = \frac{1}{K}\sum_{k=1}^{K} x_k x_k^T - m_x m_x^T \quad (5)$$

As the vector x of input variables is n-dimensional. It is obvious that the size of C_x is n × n. The elements C_x (i, i) lying in its main diagonal are the variances of x and other values C_x (i, j) determine the covariance between input variables x_i, x_j and is given by the Eq. (6) and (7):

$$C_x(i, i) = E\{(xi - mi)^2\} \quad (6)$$

$$C_x(i, j) = E\{(x_i - m_i)(x_j - m_j)\} \quad (7)$$

The rows of A in Eq. (3) are orthonormal so the inversion of PCA is possible according to relation, given by the Eq. (8):

$$x = A^T + m_x \quad (8)$$

The kernel of PCA defined by Eq. (3) has interesting properties resulting from the matrix theory which can be used in the signal and image processing to fulfil various goals such as watermarking (Khalilian and Bajic, 2013; Yassin *et al*., 2012), image compression and image enhancement etc.

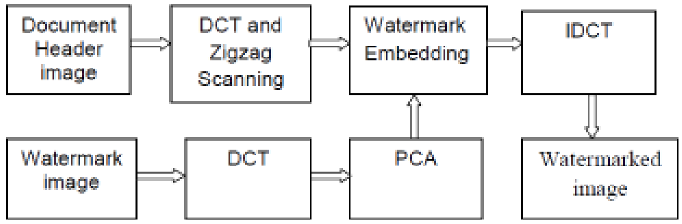

Fig. 1: Watermark embedding scheme

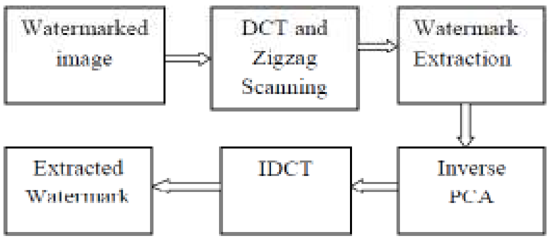

Fig. 2: Watermark extraction

PROPOSED METHODOLOGY

In this study, an efficient copyright protection scheme for the E-Governance document images has been proposed. First and foremost, Discrete Cosine Transform (DCT) is applied to the host image which is known as header image of an e-governance document and is mapped into four areas using zigzag space filling curve, which maps a 2-D mxn matrix into 1-D array of 1×m×n size.

Then the Principal Component Analysis (PCA) is applied to the DCT-transformed watermark image. Then each area is modified by the principal components of the watermark image. Watermark used is a logo image. Combination of DCT-PCA helps to improve the imperceptibility of the watermarking scheme.

Watermark embedding: Watermark embedding process is shown in Fig. 1. In embedding process, DCT is applied to the whole host image and the watermark logo image. Then, the transform coefficients of the cover image are arranged in zigzag order by using the following Eq. (9):

$$f = Zigzag(m) \quad (9)$$

where, *m* is DCT coefficients of the host image and *f* is the zigzag ordered coefficients of the host image. And it is divided into four equal parts (A_1, A_2, A_3 and A_4). PCA operation is performed on the transform coefficients of the logo watermark image.

Principle components of the watermark are embedded in all four parts (A_1, A_2, A_3 and A_4) of the cover image by using the following Eq. (10):

$$Z_i = D_i + \alpha_i * T \quad (10)$$

where, α is a scaling factor and T is the principal components of watermark image and i = 1, 2, 3, 4 for four parts of the transform coefficients of host image. Inverse zigzag and inverse DCT is applied to the modified coefficients to obtain the watermarked image.

Watermark extraction: Watermark extraction is the reverse process of watermark embedding. Initially the DCT transformation is applied to the watermarked image and then it is zigzag scanned. Zigzag scanned coefficients are divided into four sub-blocks. Inverse PCA is taken for all sub blocks to obtain the DCT transform coefficients of the watermark. Finally IDCT is applied to the coefficients to extract the watermark. Watermark extraction process is shown in the Fig. 2.

Since watermarking is performed in the frequency domain and also PCA is combined with DCT in order to increase the robustness and imperceptibility of watermarking scheme against various attacks.

EXPERIMENTAL RESULTS

Digital watermarking is performed in host or cover image, which is an e-governance document header image of size 256×1024 and the watermark image, which is a logo of the particular document of size 256×256. Both the cover and watermark images are shown in Fig. 3.

The watermark is embedded in the Header image of government of Tamilnadu by using DCT and PCA and it is shown in Fig. 4.

Watermark logo of Tamilnadu header image is extracted from the watermarked image by using reverse process from the four sub-blocks and the extracted watermarks are shown in Fig. 5.

The Proposed method is also tested with Header image of government of Kerala and the results are shown in Fig. 6 and 7, respectively.

To validate the effectiveness of our proposed watermarking scheme, experiments are performed with respect to the metric, imperceptibility. Embedding of secret message should not degrade quality of the image. To measure the quality of a watermarked image, the Peak Signal to Noise Ratio (PSNR) (Maheswari and Rameshwaran, 2012) is typically used. It is explained in the following Eq. (11) and (12):

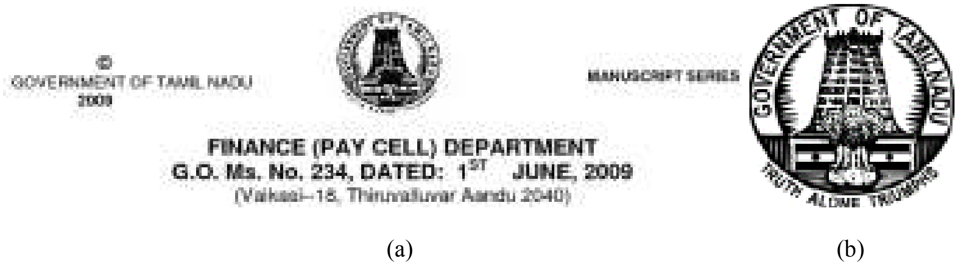

Fig. 3: (a) Header image of government of Tamilnadu, (b) watermark logo image

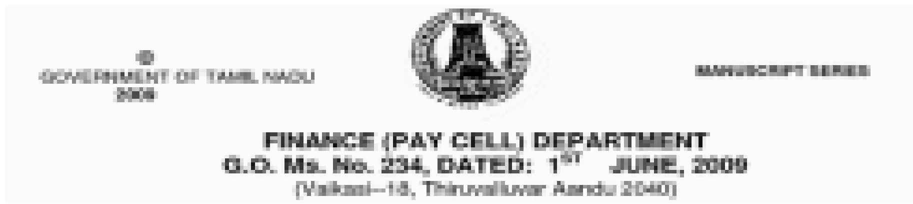

Fig. 4: Watermarked image

Fig. 5: Extracted watermarks

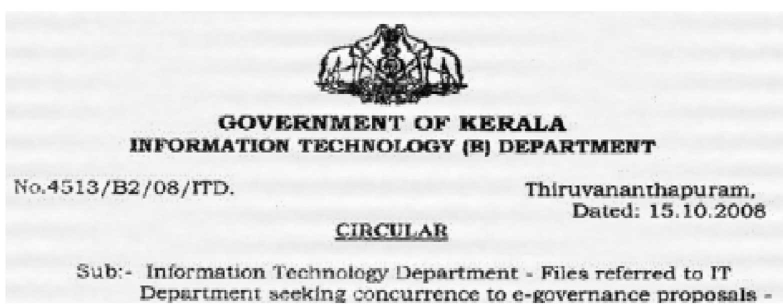

Fig. 6: Watermarked header image of Kerala

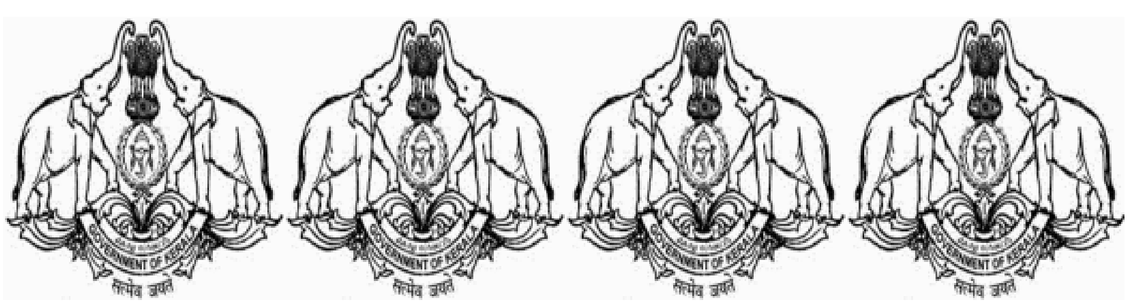

Fig. 7: Extracted watermarks

$$MSE = \sum_{i=1}^{x}\sum_{j=1}^{y}\frac{\left(|A_{ij} - B_{ij}|\right)}{x*y} \quad (11)$$

$$PSNR = 10 * \log\left(\frac{255^{2}}{MSE}\right) \quad (12)$$

Table 1: PSNR value of watermarked image

Image type	PSNR in dB	NC
Header image of government of Tamil Nadu	55.1255	1
Header image of government of Kerala	53.6944	1

Normalised Correlation (NC) between original watermark and extracted watermark from the test image is calculated by using the following Eq. (13):

$$NC = \frac{\sum_i \sum_j p_{ij} p_{ij}^*}{\sum_i \sum_j p_{ij}^2} \quad (13)$$

The proposed algorithm is tested with two header e-governance document images and the obtained PSNR is shown in Table 1. With this PSNR value no quality degradation in the watermarked image was perceived.

From the Table 1, it may be noted that the proposed method can effectively embed the watermark without any quality degradation and also the watermark is extracted perfectly.

CONCLUSION

DCT based watermarking for copyright protection of E-governance document image was proposed. The proposed method embedded the watermark using DCT and PCA. Watermarking was done in frequency domain and using a hybrid algorithm, security and imperceptibility of the e-governance document was increased. In future, the performance of the proposed algorithm may be improved by applying an optimization algorithm to optimize the scaling factor.

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