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Image Adaptive Watermarking with Visual Model in Orthogonal Polynomials based Transformation Domain

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***Abstract*—**In this paper, an image adaptive, invisible digital watermarking algorithm with Orthogonal Polynomials based Transformation (OPT) is proposed, for copyright protection of digital images. The proposed algorithm utilizes a visual model to determine the watermarking strength necessary to invisibly embed the watermark in the mid frequency AC coefficients of the cover image, chosen with a secret key. The visual model is designed to generate a Just Noticeable Distortion mask (JND) by analyzing the low level image characteristics such as textures, edges and luminance of the cover image in the orthogonal polynomials based transformation domain. Since the secret key is required for both embedding and extraction of watermark, it is not possible for an unauthorized user to extract the embedded watermark. The proposed scheme is robust to common image processing distortions like filtering, JPEG compression and additive noise. Experimental results show that the quality of OPT domain watermarked images is better than its DCT counterpart.

***Keywords*—**Orthogonal Polynomials based Transformation, Digital Watermarking, Copyright Protection, Visual model.

I. Introduction

THE explosive growth of Internet and communication networks has led to the tremendous use of multimedia data like image, audio and video. Furthermore, due to the availability of tools to manipulate digital multimedia especially digital images, tampering of such data has become very easy. In this context, it is important to ensure the integrity of images and protection against unauthorized duplication of images. A common technique for copyright protection is to embed a watermark into the image or video data to be transmitted. The important requirements of such watermarks are imperceptibility, robustness and security. Watermark imperceptibility means that the watermark should be hidden in the cover image in such a way that it cannot be seen. So it is necessary to exploit the characteristics of the human visual system (HVS) in the watermark embedding process. Robustness of a watermark is the ability to extract the watermark correctly even if intentional or unintentional attacks are made on the watermarked image. To ensure security, only the authorized user should be allowed to embed and extract the watermark. This could be achieved by employing a cryptographic key while embedding.

Several digital watermarking algorithms have been reported in the literature. Based on the domain in which the watermark is embedded, image watermarking techniques can be divided into two categories namely spatial domain techniques and frequency domain techniques. The watermark can be secret information or a content hash or another image such as a logo. The watermark is added either in the spatial domain [1- 4] or frequency domain such as DCT domain [5 -8] or Wavelet domain [9-12] or Fourier domain [13].

In [1] Swanson et al. have presented a review of several watermarking techniques for image, audio and video which are perceptually invisible or inaudible. Christen Rey and Jean-Luc Dugelay have presented a survey of various watermarking algorithms that are used for content authentication of digital images in [2]. Wang Gang et al. [3] have suggested the use of a hash function and chaotic sequence for generation of content based watermark from the original image in order to resist counterfeiting attack. Since the scheme uses LSB embedding it is prone to LSB attack. In [4] an invisible spatial domain watermarking algorithm is proposed for buyer authentication of multimedia objects wherein the watermark can be recovered even if the attacker tries to manipulate the watermark with the knowledge of the watermarking process.

Though spatial domain watermarking schemes are simple they are less resilient to common image processing operations and offer lesser embedding capacity compared to frequency domain techniques. So frequency domain techniques are more popular than the spatial domain based methods. R. B. Wolfgang et. al. [5], have designed a class of perceptual watermarks that exploit perceptual information in the watermarking process known as perceptual watermarks. These watermarks depend not only on the frequency response of the human eye, but also the properties of the image itself, to decide the watermarking strength. A DCT based watermarking scheme is proposed in [6] that takes advantage of the Human Visual System to embed the watermark. This method uses a DCT based visual model for computing the watermark embedding strength. In [7] Xia-mu Niu et al. have proposed another DCT based method of embedding a gray-

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level digital watermark in still images where a gray-level digital watermark is decomposed into a series of binary digital images by stack filter's threshold decomposition technique. Then multiple watermarking is implemented using these binary digital images. In [8] Peter H.W. Wong, Oscar C. Au and Y.M. Yeung have suggested a technique to embed multiple watermarks in the DCT domain using different keys and a technique called iterative watermark embedding, which embeds watermarks into JPEG compressed images.

In [9], Ping Dong et. al. have proposed two watermarking approaches that are robust to geometric distortions. The first approach is invariant to affine transform attack and is based on image normalization. The second approach is based on a watermark re-synchronization scheme that aims to alleviate the effects of random bending. Both the schemes employ a direct-sequence code division multiple access approach to embed a multi-bit watermark in the DCT domain of the image. In [10] Christine I. Podilchuk and Wenjun Zeng have proposed two image-adaptive watermarking techniques. The first technique makes use of a DCT based visual mask and the second method is based on a visual model using four-level wavelet decomposition. In [11], Ko-Ming Chan et al. have proposed a public watermarking system that embeds a couple of watermarks: a fragile watermark in the spatial domain and a semi-fragile watermark in the frequency domain. They employ the advanced encryption standard to make the watermarking algorithm public. In [12], Wei Z. H. et al. have applied Just Noticeable Distortion feature of human visual system to embed an invisible watermark in the wavelet transform domain. Ching-Yung Lin et. al. have described a watermarking scheme in [13], in which the watermark is embedded into Fourier transform domain of the cover image. This technique tolerates mild JPEG compressions only.

From all these literatures, it is evident that digital watermarking in frequency domain is attractive and superior when compared to spatial domain watermarking. Also the choice of transformation and achieving imperceptibility play a significant role in case of the frequency domain invisible watermarking techniques. Hence in this paper, an image adaptive invisible watermarking scheme that uses a visual model designed in the orthogonal polynomials based transform domain is proposed for still images.

The paper is organized as follows. In Sections II and III the proposed Orthogonal Polynomials based transformation is presented. The proposed visual model used to generate the Just Noticeable Distortion (JND) mask is presented in Section IV and the watermark embedding and extraction techniques are presented in section V. In Section VI, the experimental results are presented.

II. Orthogonal Polynomials Based Transformation

We consider a linear 2-D image formation system around a Cartesian coordinate separable, blurring, point spread operator in which the image I results in the superposition of the point source of impulse weighted by the value of the object function f. Expressing the object function f in terms of derivatives of the image function I relative to its Cartesian coordinates is very useful for analyzing the image. The point spread function $M(x, y)$ can be considered to be a real valued function defined for $(x, y) \in X$ x Y, where X and Y are ordered subsets of real values. In case of gray-level image of size $(n$ x $n)$ where X (rows) consists of a finite set, which for convenience can be labeled as $\{0, 1, \ldots, n\text{-}1\}$, the function $M(x, y)$ reduces to a sequence of functions.

$$M(i, t) = u_i(t), \qquad i, t = 0, 1, \ldots, n\text{-}1 \tag{1}$$

The linear two dimensional transformation can be defined by the point spread operator $M(x, y)(M(i, t) = u_i(t))$ as shown in equation (2).

$$\beta'(\zeta, \eta) = \int_{x \in X} \int_{y \in Y} M(\zeta, x)\, M(\eta, y)\, I(x, y)\, dxdy \tag{2}$$

Considering both X and Y to be a finite set of values $\{0, 1, 2 \ldots n-1\}$, equation (2) can be written in matrix notation as follows

$$\left|\beta'_{ij}\right| = \left(|M| \otimes |M|\right)^{t} |I| \tag{3}$$

where $\otimes$ is the outer product, $|\beta'_{ij}|$ are n^2 matrices arranged in the dictionary sequence, $|I|$ is the image , $|\beta'_{ij}|$s are the coefficients of transformation and the point spread operator |M| is

$$|M| = \begin{vmatrix} u_0(t_1)\ u_1(t_1) \cdots u_{n-1}(t_1) \\ u_0(t_2)\ u_1(t_2) \cdots u_{n-1}(t_2) \\ \vdots \\ u_0(t_n)\ u_1(t_n) \cdots u_{n-1}(t_n) \end{vmatrix} \tag{4}$$

We consider a set of orthogonal polynomials $u_0(t)$, $u_1(t)$, …, $u_{n-1}(t)$ of degrees 0, 1, 2, …, n-1, respectively to construct the polynomial operators of different sizes from equation (4) for $n \geq 2$ and $t_i = i$. The generating formula for the polynomials is as follows.

$$u_{i+1}(t) = (t - \mu)u_i(t) - b_i(n)u_{i-1}(t) \text{ for } i \geq 1, \qquad u_1(t) = t - \mu, \text{ and } u_0(t) = 1, \tag{5}$$

where

$$b_i(n) = \frac{\langle u_i, u_i \rangle}{\langle u_{i-1}, u_{i-1} \rangle} = \frac{\sum_{t=1}^{n} u_i^2(t)}{\sum_{t=1}^{n} u_{i-1}^2(t)} \text{ and } \mu = \frac{1}{n}\sum_{t=1}^{n} t$$

Considering the range of values of t to be $t_i = i$, $i = 1, 2, 3, \ldots n$, we get

$$b_i(n) = \frac{i^2\left(n^2 - i^2\right)}{4\left(4i^2 - 1\right)}, \mu = \frac{1}{n}\sum_{t=1}^{n} t = \frac{n+1}{2}$$

III. The Orthogonal Polynomial Basis

For the sake of computational simplicity, the finite Cartesian coordinate set X and Y are labeled as $\{1, 2, 3\}$. The point spread operator in equation (3) that defines the linear orthogonal transformation for image coding can be obtained as $|M| \otimes |M|$, where $|M|$ can be computed and scaled from equation (4) as follows:

$$|M| = \begin{vmatrix} u_0(x_0) & u_1(x_0) & u_2(x_0) \\ u_0(x_1) & u_1(x_1) & u_2(x_1) \\ u_0(x_2) & u_1(x_2) & u_2(x_2) \end{vmatrix} = \begin{vmatrix} 1 & -1 & 1 \\ 1 & 0 & -2 \\ 1 & 1 & 1 \end{vmatrix} \quad (6)$$

The set of polynomial operators $O_{ij}^n (0 \le i, j \le n\text{-}1)$ can be computed as

$$O_{ij}^n = \hat{u}_i \otimes \hat{u}_j^t$$

where $\hat{u}_i$ is the $(i+1)^{st}$ column vector of $|M|$.

The following symmetric finite differences for estimating partial derivatives at (x, y) position of the gray level image I are analogous to the eight finite difference operators O_{ij}s e xcluding O_{00}.

$$\frac{\partial I}{\partial y}\Big|_{x,y} = \sum_{i=-1}^{1} [I(x-i, y+1) - I(x-i, y-1)]$$

$$\frac{\partial I}{\partial x}\Big|_{x,y} = \sum_{i=-1}^{1} [I(x+1, y-i) - I(x-1, y-i)]$$

$$\frac{\partial^2 I}{\partial y^2}\Big|_{x,y} = \sum_{i=-1}^{1} [I(x-i, y-1) - 2I(x-i, y) + I(x-i, y+1)]$$

$$\frac{\partial^2 I}{\partial x^2}\Big|_{x,y} = \sum_{i=-1}^{1} [I(x-1, y-i) - 2I(x, y-i) + I(x+1, y-i)] \quad (7)$$

and so on. In general,

$$\frac{\partial^{i+j}}{\partial x^i \partial y^j} = |O_{ij}| \text{ and}$$

$$\frac{\partial^{i+j} I}{\partial x^i \partial y^j} = (|O_{ij}|, |I|) = \beta'_{ij}, \quad 0 \le i, j \le 2 \text{ and } i = j \ne 0 \quad (8)$$

where | | indicates the arrangement in dictionary sequence and (,) indicates the inner product. Hence, O_{ij}s are symmetric finite difference operators. β'_{ij}s are the coefficients of the linear transformations and are defined as follows.

$$|\beta'_{ij}| = |M|^t |I| \quad (9)$$

where $|M|$ is the 2-D point-spread operator defined as $|M| = |M| \otimes |M|$. The complete set of basis operators of size (2 X 2) are given below.

$$[O_{00}^2] = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \quad [O_{01}^2] = \begin{bmatrix} -1 & 1 \\ -1 & 1 \end{bmatrix}$$

$$[O_{10}^2] = \begin{bmatrix} -1 & -1 \\ 1 & 1 \end{bmatrix} \quad [O_{11}^2] = \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$$

It can be shown that a set of $(n \times n)$ $(n \ge 2)$ polynomial operators forms a basis, i.e. it is complete and linearly independent.

Having described the transformation, we present the proposed visual model in the following section.

IV. THE OPT BASED VISUAL MODEL

In order to imperceptibly embed a watermark in a cover image, the limit to which an image can be distorted without making the difference between the original image and the altered image perceptible, must be estimated. This limit is image dependent and is called the *Just Noticeable Distortion* (*JND*). To make an accurate estimation of the *JND*, low level image characteristics like textures, edges and luminance are taken into account, since several studies about the human visual system have revealed that the distortion visibility in highly textured areas is least compared to edge areas where distortion visibility is quite high. So we propose to first analyze the low level features such as textures, edges and luminance of the cover image in orthogonal polynomials based transform domain in order to identify the blocks with highly textured areas and blocks containing edges. We also compute the luminance of the blocks and construct a OPT based visual model similar to the DCT based model described in [6], by generating a *JND* mask to provide content based adaptability while embedding. We first apply the proposed orthogonal polynomials based transformation on the cover image after partitioning the image into non-overlapping blocks of size $(N \times N)$ to obtain the transformed blocks $[\beta'_{ij}]$ and then we analyze these coefficients to determine the measure of textures, edges and luminance.

In the following subsections we describe the process of estimation of texture, edge and luminance information in the proposed OPT based transformation.

A. Estimation of Texture information

Being unitary and complete, the averaging factor of the orthogonal polynomial transformation namely β'_{00} is taken as the DC coefficient and the remaining β'_{ij} values are the AC coefficients which is analogous to other transformations. We deduce the first measure to be incorporated in the *JND* mask namely the texture information (T_b) within each block based on the energy of the coefficients β'_{ij} $\{0 < i < N$ and $0 < j < N\}$ since these coefficients mainly contribute towards the texture of the image, using the following equation.

$$T_b = \frac{N^2 \times TE_b}{TE_{b\max}} \quad (10)$$

where $TE_b = \log \sum_{i=1}^{N-1} \sum_{j=1}^{N-1} (\beta'_{ij})^2$

The TE_b values are then normalized to the range $(1 \ldots N^2)$. $TE_{b\max}$ is the maximum value of TE_b over all the blocks in the image. T_b is computed for every block in the image.

B. Estimation of edginess

Secondly, we detect edge points in the blocks by modeling an edge detector based on the gradient defined in terms of the transformed coefficients β'_{ij}. These β'_{ij} values are approximations of the partial derivatives of various order of the image region as shown in Section III. For example, O_{01} denotes first order differencing operation in y direction, $\left(\frac{\partial}{\partial y}\right)$ and O_{10} denotes the first order differencing operation in x direction, $\left(\frac{\partial}{\partial x}\right)$ etc. O_{00} gives the local averaging operator. Excluding O_{00}, the remaining operators can be considered for computing the gradient. Considering only the first order differences, namely, β'_{01}, β'_{10} the gradient

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magnitude in the orthogonal polynomials based transform domain can be computed as

$$\text{Gradient magnitude} = \sqrt{\beta_{10}^{'2} + \beta_{01}^{'2}}$$

and can be used against a threshold T for detection of edges. The polynomial operators, o_{01} and o_{10} are modeled to be the gradient edge detectors because of their large values in regions having prominent edges and small values on nearly uniform gray level regions. Having modeled the edge detector we extract the binary edge map of the cover image using the polynomials based edge operator.

After extracting the binary edge map, we count the number of edge points in each block. Let the number of edge points in block b be EC_b. The edginess E_b of every block is calculated as follows

$$E_b = \frac{N^2 \times EC_b}{EC_{b\max}} \quad (11)$$

where $EC_{b\max}$ is the maximum value of EC_b over all the blocks in the image.

C. Estimation of Luminance

The third measure namely the luminance which is defined as the way in which the human eye perceives brightness, is determined by considering the averaging factor of the orthogonal polynomials based transformation (β'_{00}) alone, because much of the information pertaining to luminance in the block is carried by this coefficient. We estimate the mean luminance L_b of a block b using the formula

$$L_b = \frac{\beta'_{00b}}{\beta'_{00mean}} \quad (12)$$

where $\beta'_{00mean} = \frac{\left(\sum_{i=1}^{Nb} \beta_{00i}\right)}{Nb}$ and Nb is the number of blocks.

Finally, after obtaining the values corresponding to texture, edges and luminance, we formulate the visual model by generating the *JND* mask to be used for watermark embedding using the following equation

$$JND = (T_b - E_b) \times (L_b)^{\delta} \quad (13)$$

where δ is the parameter used to control luminance sensitivity. We present the proposed watermarking scheme in the following section.

V. Proposed Image Adaptive Watermarking in OPT Domain

A. Watermark embedding

The proposed watermarking algorithm starts by partitioning the cover image *I* of size (*P* x *Q)* into (*N* x *N)* non-overlapping blocks. The watermark image (logo or trademark) *W* is of size (*P1* x *Q1)* where *P1* < *P* and *Q1* < *Q* The proposed orthogonal polynomials based transformation described in Section III is applied on the cover image to obtain the transformed blocks and the blocks are arranged in a 1-D zig-zag sequence. The secret key *sk* is employed in generating pseudorandom noise sequences (*PN* sequences) used to represent the watermark bits '0' and '1'. It is also used in choosing the mid frequency *AC* coefficients of the cover image in which the *PN* sequences corresponding to the bits in the watermark are embedded. We then embed the watermark using the relation,

$$I_k = I_k + JND * \alpha * PN_k \quad \ldots (14)$$

where I_k are the chosen mid frequency *AC* coefficients of the cover image, α is the scaling factor, *JND* is the mask value of the corresponding block, derived from the visual model proposed in Section IV and PN_k is the *PN* sequence representing the watermark bits.

The steps involved in the proposed OPT domain embedding is presented hereunder as an algorithm:

Input: Cover Image *OI* of size *(P* x *Q)*, watermark image *W* of size *(P1* x *Q1)*

Begin

1. Partition the original image *OI* into (*N* x *N*) non-overlapping blocks. Obtain the transformed blocks $[\beta I'_{ij}]$ $\{0 \le i < N;\ 0 \le j < N\}$ of *OI* by applying the orthogonal polynomials based transformation described in section II.
2. Generate two uncorrelated pseudorandom noise sequences (PN-sequences) PN_0 and PN_1 to embed the watermark bits 0 and 1 respectively, using sub-keys *sk1* and *sk2* generated from the secret key, as the seed to the pseudo-random sequence generator. Repeat steps 4 to 9 for all the blocks until there are bits to embed.
3. Compute the texture information TE_b in the current block of the cover image as follows
$$TE_b = \log \sum_{i=1}^{N-1} \sum_{j=1}^{N-1} (\beta I'_{ij})^2$$
$$T_b = \frac{N^2 \times TE_b}{TE_{b\max}}$$
4. Compute the edginess of the block as follows
$$E_b = \frac{N^2 \times EC_b}{EC_{b\max}}$$
where EC_b is the number of edge points in the current block and is calculated by applying the polynomials based edge operator as described in the sub-section *IV B*. $EC_{b\max}$ is the maximum value of EC_b over all the blocks in the image.
5. Compute the luminance of the block as follows
$$L_b = \frac{\beta I'_{00}}{\sum_{i=1}^{Nb} \beta I'_{00\,i}}$$
where *Nb* is the number of blocks in the cover image.
6. Compute *JND* using the formula

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$$JND = (T_b - E_b) \times (L_b)^{\delta}$$

where δ is the parameter used to control luminance sensitivity.

7. Arrange the coefficients $\beta I'ij$ into a 1-D zig-zag sequence to obtain the vector *I*.
8. Choose *n* coefficients from the 1-D sequence *I* employing the random sequence S_i $\{S_i \in \{4, 5 \ldots (N^2\text{-}4)\}$ and $1 \le i \le n\}$ generated with the sub-key *sk3* generated from the secret key, as the seed to the pseudo-random sequence generator. Let the group of coefficients chosen be I_k. Compute

$$I_k = \begin{cases} I_k + JND * \alpha * PN_0 & \text{if the watermark bit is 1} \\ I_k + JND * \alpha * PN_1 & \text{otherwise} \end{cases}$$

if there are bits left to embed.

9. Apply orthogonal polynomials basis described in section III to get the watermarked image *WI*.

End

Output: Watermarked Image *WI*.

The entire process of embedding with the proposed orthogonal polynomials is depicted in Figure 1.

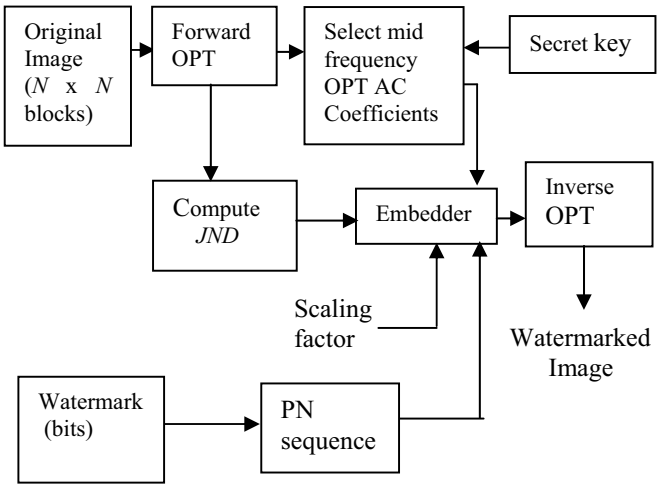


Fig. 1. Embedding process Watermark extraction

B. Watermark extraction

To extract the watermark we first partition the original image *OI* into blocks of size (*N* x *N*). Then blocks of OPT coefficients are computed by applying the proposed transformation on the original image and the watermarked image and the difference between the two are computed to extract the watermark. The correlation coefficient between the extracted watermark and the original watermark is computed to decide whether the extracted watermark is acceptable.

The watermark extraction algorithm is presented below.

Input : Watermarked Image *WI* , original image *OI* of size (*P* x *Q)* and original watermark *OW* of size (*P1* x *Q1)*

Begin

1. Partition the original image *OI* and the watermarked image *WI* into (*N* x *N*) non-overlapping blocks.
2. Obtain the transformed blocks $[\beta I'_{ij}]$ and $[\beta W'_{ij}]$ $\{0 \le i < N;\ 0 \le j < N\}$ of *OI* and *WI* respectively by applying the orthogonal polynomials based transformation described in section 2. Repeat steps 3 to 5 for all the blocks.
3. Arrange $[\beta I'_{ij}]$ in 1-D zig-zag sequence.
4. Choose *n* coefficients from the 1-D sequence using the random sequence *Si* where $\{Si \in \{4,5 \ldots N2\}$ and $\{1 \le i \le n\}$ as described in the embedding algorithm. Let the group of coefficients chosen be *OIk* and *WIk* .
5. Regenerate the two pseudorandom sequences PN_0 and PN_1 using the same seed as in the embedding process.
6. Compute

$$PN_k^* = (WI_k - OI_k)/(\text{JND}^* \alpha) .$$

7. For each block, the correlation between PN_k^* and the pseudorandom sequences PN_0 and PN_1 are computed. If the correlation with PN_0 is higher than the correlation with PN_1 then the extracted bit is considered to be 0, otherwise the extracted bit is considered to be 1.
8. Reconstruct the watermark *W** using the extracted watermark bits.
9. Compute the correlation coefficient between *W** and the original watermark *OW* as described in Equation (16). If this correlation value is greater than a threshold *T*, the watermark is acceptable.

End

Output : Extracted Watermark.

VI. Measure of Performance

The performance of the proposed watermarking scheme with orthogonal polynomials based transform coding is measured by computing the peak signal-to-noise ratio (PSNR), which is defined as

$$PSNR = 10 \log_{10} \frac{(255)^2}{e_{ms}^2} \qquad (15)$$

where the average mean-square error, e_{ms} is,

$$e_{ms}^2 = \frac{1}{PQ} \sum_{i=1}^{P} \sum_{i=1}^{Q} E(u_{i,j} - u'_{i,j})^2$$

where $u_{i,j}$ and $u'_{i,j}$ represent the *(P* x *Q)* original and reproduced images respectively.

Another measure is also used to assess the correlation between the original watermark and the extracted watermark. The correlation between the corresponding pixels of two images *I* and *I'* of size (*P* x *Q)*, are analyzed by calculating the correlation coefficients using the following formulae

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$$r_{xy} = \frac{\mathrm{cov}(x, y)}{\sqrt{D(x)\sqrt{D(y)}}} \tag{16}$$
$$E(x) = \frac{1}{PQ}\sum_{i=1}^{PQ} x_i$$
$$D(x) = \frac{1}{PQ}\sum_{i=1}^{PQ} \left(x_i - E(x)\right)^2$$
$$\mathrm{cov}(x, y) = E(x_i - E(x))(y_i - E(y))$$

where $E(x)$ is the estimation of mathematical expectations of x, $D(x)$ is the estimation of variance of x and $\mathrm{cov}(x, y)$ is the estimation of covariance between x and y, where x and y are grey-scale values of corresponding pixels of images I and I'.

VII. Experimental Results

The proposed OPT domain watermarking technique has been experimented with 150 different images and the results are reported in this section. The test images are of size (256 x 256) with pixel values in the range 0 - 255. One such standard cover image namely Lena image is shown in Figure 2(a). These cover images are partitioned into (4 x 4) non-overlapping blocks and the proposed orthogonal polynomials based transformation is applied on each block as described in section II. Then the resulting 2-D transformed coefficients are re-arranged into a 1-D zigzag sequence $[\beta'_k]$. We use a secret key with eight characters from which sub-keys are formed and used to generate pseudorandom numbers which are employed to select mid frequency β'_k s to form the host vector to embed the watermark. We choose mid-frequency transformed coefficients to form the host vector, as these coefficients tend to have large energies so that the embedded watermarks tend to be robust against different kinds of attacks. Then two uncorrelated pseudorandom noise (*PN*) sequences are generated which represent the '0' and '1' bits of the watermark to be embedded. We consider different watermark images, all of size (16 x 16). One such watermark image is shown (enlarged for visibility) in Figure 2(b). The *PN* sequences corresponding to the watermark bits are embedded into the transformed coefficients of the cover image using the embedding function given in equation (14) after calculating the *JND* mask as described in Section *IV*. The Lena image watermarked with this watermark image is shown in Figure 2(c). We measure the performance of the proposed watermarking scheme by calculating the Peak Signal to Noise Ratio (PSNR) between the original and the watermarked Lena images as described in Section *VI*. With the lena image (Figure 2(a)) as the cover and the watermark image (Figure 2(b)), we obtain a PSNR value of 46.82 dB and the corresponding watermarked image is shown in Figure 2(c). The experiment is repeated by embedding the watermark in different cover images and the results are incorporated in Table I. The PSNRs of almost all the OPT domain watermarked images are found to be above 45 dB, signifying that the quality of the cover image is not much degraded.

To measure the efficiency of the proposed orthogonal polynomials based watermarking, experiment is conducted with the DCT-based watermarking scheme implemented by replacing the proposed visual model by the DCT-based visual model described in [6]. The original Lena image shown in Figure 2(a) is embedded with the watermark image shown in Figure 2(b) using the DCT-based watermarking scheme and the PSNR value for the same is found to be 45.15 dB. The same experiment is repeated for different cover images and the PSNR values obtained are incorporated in the same Table I. From Table I it is evident that the proposed OPT based watermarking scheme outperforms its DCT counterpart.

The watermark embedded in the test images with the proposed OPT based watermarking scheme is extracted as described in section V*B*. The correlation coefficient between the original watermark and the extracted watermark is calculated and the same is presented in Table II. From this table it is evident that there is good correlation between the original watermark and the extracted watermark.



(a) (b)



(c)

Fig. 2 (a) Original Lena (b) Watermark (c) Watermarked Image using the proposed scheme

TABLE I. PSNR FOR OPT AND DCT WATERMARKED IMAGES

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Image	PSNR (dB)	
	Proposed OPT domain Watermarking	DCT domain Watermarking
Lena	46.82	45.15
Mandrill	45.49	42.92
Peppers	47.68	44.22
Girl	46.56	43.27
Houses	47.17	44.32

TABLE II. CORRELATION OF EXTRACTED OPT DOMAIN WATERMARK WITH THE ORIGINAL WATERMARK

Image	Correlation Coefficient
Lena	0.889
Mandrill	0.835
Peppers	0.811
Girl	0.852
Houses	0.817

In order to test the robustness of the watermark, various incidental distortions like filtering, JPEG compression and noise are applied to the watermarked images. For example, uniform noise (15%) and Gaussian noise (5%) are added to the Lena image watermarked with the proposed scheme and the corresponding images are shown in Figure 3(a) and 3(c). We then extract the watermark using the extraction algorithm described in Section V*B*. We are able to extract the watermarks with some distortion and the same are presented in Figure 3(b) and 3(d).

Next we apply median filtering with radius-3 pixels to the Lena image watermarked using the proposed scheme and the filtered image is shown in Figure 4(a). Similarly we apply high-pass filtering (radius-12 pixels) to the watermarked Lena image and the filtered image is shown in Figure 4(c). We then extract the watermarks from these filtered images using the extraction algorithm described in Section V*B*. We are able to recover the watermarks successfully with some distortions as depicted in Figures 4(b) and 4(d).



(a) (b)



(c) (d)

Fig. 3. (a) OPT watermarked image with 15% uniform noise, (b) Watermark extracted from Figure 3(a), (c) OPT watermarked image with 5% Gaussian noise, (d) Watermark extracted from Figure 3(c)



(a) (b)

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(c) (d)

Fig. 4. (a) Median filtering with a radius of 3 pixels on OPT watermarked image, (b) Extracted watermark from Figure 4(a), (c) High-pass filtering with a radius of 12 pixels OPT watermarked image, (d) Extracted watermark from Figure 4(b)

In order to compare the robustness of the OPT domain watermarking scheme, the same incidental distortions are applied to the images watermarked using the adaptive watermarking scheme based on DCT and we try to extract the watermark embedded. We observe that the proposed OPT based scheme is robust to higher percentage of additive noise i.e. 15% of uniform noise and 5% of Gaussian noise while its DCT counterpart is robust to only 5% of uniform noise and 2% of Gaussian noise and the watermark becomes completely irrecoverable if the noise percentage is increased . While both the schemes can tolerate JPEG compression with quality factor 10, the proposed scheme has shown better robustness to high-pass filtering with a radius of 12 pixels.



(a) (b)

Fig. 5. (a) JPEG Compressed (Quality factor = 10) OPT watermarked image, (b) Extracted watermark from Figure 5(a).

VIII. Conclusion

An image adaptive invisible watermarking technique with Orthogonal Polynomials based Transformation has been presented in this paper. In this method, the orthogonal polynomial transform is applied on non-overlapping blocks of the cover image as well as the watermark image and the watermark is embedded in a content adaptive manner by controlling the embedding strength using a Just Noticeable Distortion mask derived in the orthogonal polynomials based transform domain. The proposed OPT based watermarking technique is experimented on different images and is compared with its DCT-based counterpart. The achieved image quality is found to be better in the case of the OPT based watermarking. Since the technique uses a secret key for selecting the coefficients, it is not possible for unauthorized users to alter or remove the watermark. Also the watermark is found to be robust to common image processing distortions such as filtering, JPEG compression and additive noise.

References

[1] Mitchell D. Swanson, Mei Kobayashi and Ahmed H. Tewfik, "Multimedia Data-Embedding and Watermarking Technologies", *Proceedings of the IEEE*, Vol. 86, No. 6, pp. 1064-1087, 1998.

[2] Christen Rey and Jean-Luc Dugelay, "A Survey of Watermarking Algorithms for Image Authentication," *EURASIP Journal on Applied Signal Processing,* Vol. 6, pp. 613-621, 2002.

[3] Wang Gang and Rao Ni-ni, "A fragile watermarking scheme for Medical Image", *Proceedings of the 2005 IEEE Engineering in Medicine and Biology 27th Annual Conference, China,* pp. 3406-3409, 2005.

[4] Dipti Prasad Mukherjee, Subhamoy Maitra, and Scott T. Acton, "Spatial Domain Digital Watermarking of Multimedia Objects for Buyer Authentication", *IEEE Transactions on Multimedia,* Vol. 6, No. 1, pp. 1-19, 2004.

[5] R.B. Wolfgang, C.I. Podilchuk and E.J. Delp, "Perceptual Watermarks for Digital Images and Video," *Proceedings of the IEEE,* Vol. 87, No. 7, pp. 1108-1126, 1999.

[6] S. Kay and E. Izquierdo, "Robust content based image watermarking," *Proceedings of the Workshop on Image Analysis for Multimedia Interactive Services, WIAMIS'2001, Tampere, Finland,* 2001.

[7] Xia-mu Niu, Zhe-ming and Sheng-ho Sun, "Digital watermarking of still images with Gray-level digital watermarks," *IEEE Transactions on Consumer Electronics,* Vol. 46, No. 1, pp. 137-145, 2000.

[8] Peter H.W. Wong, Oscar C. Au and Y.M. Yeung, "A Novel Blind Multiple Watermarking Technique for Images," *IEEE Trans. on Circuits and Systems for VideoTechnology,* Vol. 13, No. 8, pp. 813-830, 2003.

[9] Ping Dong, Jovan G. Brankov, Nikolas P. Galatsanos, Yongyi Yang and Frank Davoine, "Digital Watermarking Robust to Geometric Distortions," *IEEE Transactions on Image Processing,* Vol. 14, No. 12, pp. 2140-2149, 2005.

[10] Christine I. Podilchuk and Wenjun zeng, " Image-Adaptive Watermarking Using Visual models," *IEEE Journal on Selected areas in communications*, Vol. 16, No. 4, pp. 525-539, 1998.

[11] Ko-Ming Chan and Lon-Wen Chang, " A Novel Public Watermarking System based on Advanced Encryption System," *Proceedings of the 18th International Conference on Advanced Information Networking and Application, IEEE Computer Society (AINA'04),* 2004.

[12] Wei Z. H., Qin P. and Fu Y. Q., "Perceptual digital watermark of image using wavelet transform", *IEEE Transactions on Consumer Electronics*, Vol. 44, No. 4, 1267-1272, 1998

[13] Ching-Yung Lin, Min Wu, J. Bloom, Ingemar J. Cox, Matt L.Miller and Yui Man Lui, "Rotation, Scale and Translation Resilient Watermarking for Images," *IEEE Transactions on Image Processing,* Vol. 10, No. 5, pp.767-782, 2001.