
Jantana Panyavaraporn
Department of Telecommunications Engineering, Faculty of Engineering
King Mongkut’s Institute of Technology Ladkrabang, Bangkok 10520, Thailand
jippy26@hotmail.com

Yuttapong Rangsanseri
Department of Telecommunications Engineering, Faculty of Engineering
King Mongkut’s Institute of Technology Ladkrabang, Bangkok 10520, Thailand
rangsanseri@yahoo.com

Abstract: In this paper, we present a watermarking technique for hiding an entire image or pattern as a watermark into remote-sensing images. In our technique, the Karhunen Loève Transform (KLT) is preliminarily applied on the multispectral image. The most principal component image is used for embedding with a watermark. The embedding process is performed in a middle-frequency subband resulted by a two-dimension wavelet transform. Finally, the multispectral image containing the watermark is obtained by the inverse KLT. Experimental results on LANDSAT images showed that the proposed watermarking technique is robust to various kinds of attacks.

Keywords: Karhunen Loève Transform, Wavelet, Watermarking, Remote Sensing, Multispectral Image

1. Introduction

The significance of image watermarking is increasing as the digital communication becomes more dominating. Through watermarking the owner of the image can authenticate the authorized use of the image [1]. In steganography, the purpose is to include the actual message as a watermark into the information carrying image [2].

In this study we consider the watermarking of remote-sensing images. In multispectral mode, the images contain multifold bands compared to the three bands in RGB-color images. Watermarking color images has been largely studied [3] [4]. Most promising methods include watermarking in transform domain [4] [5], but the watermark can be inserted also in the original spatial domain [6]. Also multispectral and satellite images have been considered for watermarking [7] [8] [9].

In [7], both the bandwise discrete Fourier transform and the bandwise discrete wavelet transform was applied in embedding the watermark. The invisibility constraint was satisfied by the near-lossless paradigm. The method is valid according to the experiments in clipping and classification. In [8], the grayscale watermark was embedded in the transform domain of the multispectral image. The Karhunen Loève Transform (KLT) provided the eigenimages and the watermark was embedded in one of the eigenimages. The reconstruction spreads the watermark into the whole spectral image according to the KLT.

2. The Proposed Method

In our research, a binary image such as a company’s logo is considered as the watermark. The watermarking is performed on the most principal component image resulted by applying the KLT on the multispectral image. The image is decomposed by a multistage wavelet transform, and a middle-frequency subband is modified according to the content of the watermark. This method does not require the original image to recover the embedded signature.

The watermarking consists of three main steps: KLT process, watermark embedding and watermark detecting. We will describe the processes as follows.

1) Watermarking via KLT

Fig.1 shows the block diagram of the watermark embedding process. First, the multispectral image is brought to the KLT process as \( n \)-dimension vectors being \( n \) the number of spectral bands. Let \( X \) be the vector containing the \( n \) components for a given pixel and \( U \) the mean vector \( U = E[X] \). The covariance matrix \( C_x \) is defined as:

\[
C_x = E [(X - U)(X - U)]
\]

(1)
The KLT (\(T\)) is defined as the one that diagonalizes \(C_x\) in the following way:

\[
C_Y = T C_X T^T = \Lambda
\]  

(2)

Being \(C_Y\) the covariance of the transformed vector (\(Y\)) and \(\Lambda\) the diagonal matrix representing eigenvalues, \(Y\) can then be obtained by the equation:

\[
Y = T(X - U)
\]  

(3)

Since the transformation optimally diagonalizes the co-variance matrix between spectral bands, the spectral correlation of the transformed components is removed. The images in the transformed domain are sorted in order of importance or with decreasing variance. This energy compaction in the spectral axis is quite suitable for selection to insert the watermark.

Fig. 2 shows the block diagram of the watermark extracting process. Before extracting the watermarked image will transform by KLT process to get most principal component as described.

2) Watermark Embedding

Fig. 3 shows the block diagram of the watermark embedding. First, the binary signature image is produced as a bit sequence of watermark \(S\). The data pixels are valued as 1 and the background pixels are valued as –1,

\[
S = \{s_i, 1 \leq i \leq M, s_i \in \{-1, 1\}\}
\]  

(4)

where \(M\) is the total number of pixel in the signature image (\(M\) is equal to 1/16 \(N_xN\)).

The pseudo-random sequence \(P\) which each number can take a value either 1 or –1 is equi-probably generated with a secret key for embedding and extracting of the watermark.

\[
P = \{p_i, 1 \leq i \leq M, p_i \in \{-1, 1\}\}
\]  

(5)
The two-level DWT of \( N \times N \) image (I) is computed. A binary signature is embedded only in \( LH_2 \) subband. \( T = \{ t_i, 1 \leq i \leq M \} \). The watermark is embedded into the vector \( T \), to obtain a new vector \( T' = \{ t'_i, 1 \leq i \leq M \} \) according to the following rule:

\[
t'_i = t_i + \alpha_p . s_i, i = 1, 2, ..., M
\]

(6)

where \( \alpha \) is a magnitude factor which is a constant determining the signature strength. The value is selected to offer a trade-off between robustness and unobtrusiveness. The inverse DWT is then performed to obtain the watermarked image \( I' \).

3) Watermark Extracting

Fig. 4 shows the block diagram of the watermark extracting process. The watermark extracting can be performed without knowledge of the original image. Instead, a prediction of the original value of the pixels is needed. The watermarked image may be considered to be the original image that is perturbed by the pseudorandom noise. Thus, a prediction of the original value of the pixels is to use noise-elimination technique. In this paper we use a \( 5 \times 5 \) mask and all elements are equal to 1/25. The predicted image \( \hat{I} \) can be obtained by smoothing the input image \( I' \) with a spatial convolution mask. The prediction of the original value can be defined as:

\[
\hat{i}_k = \frac{1}{c \times c} \sum_k i_k
\]

(7)

where \( c \) is the size of the convolution mask. The watermarked image and the predicted image are DWT transformed independently, and of each the \( LH_2 \) subband is selected to generate a vector \( T^* \) and \( \hat{T} \) respectively.

From Eq. (6), the estimate of the watermark \( \hat{S} \) is indicated by the difference between \( T^* \) and \( \hat{T} \) the equation can be represented as:

\[
\hat{\delta} = t^*_i - \hat{t}_i = \alpha_p . s_i
\]

(8)
Therefore, the sign of the difference between the predicted and the actual value is the value of the embedded bit:

\[ sgn(\delta_i) = p_i \cdot \hat{s}_i \]  

(9)

The watermark can then be estimated by multiplying pseudo-random number to the embedded bit. If a wrong pseudo-random sequence is used, the scheme does not work.

![Diagram of watermarking process in wavelet domain](image)

**Fig. 4** Watermark extracting process in wavelet domain

### 3. Performance Evaluation

To evaluate the performance of the proposed algorithm, a similarity measurement between the original signature \( S \) and the extracted signature \( S' \) is computed by using the normalized correlation:

\[
\text{Normalized Correlation (NC)} = \frac{\sum_{i=1}^{M} S_i S'_i}{\sum_{i=1}^{M} S_i^2}
\]

(10)

Also, the quality is of the watermarked image, compared to the original image, is measured based on the Peak Signal to Noise Ratio (PSNR) which is defined by:

\[
PSNR = 10 \log \left( \frac{255^2}{MSE} \right)
\]

(11)
where

\[ MSE = \frac{1}{n \times N \times N} \sum_{b=1}^{n} \sum_{i=1}^{N} \sum_{j=1}^{N} \left[ X(b,i,j) - Y(b,i,j) \right]^2 \]  

(12)

is the mean square error between the original image (X) and the watermarked result (Y) where (i, j) denotes the specific pixel value.

4. Experimental Results

A 3-band LANDSAT image, size of 512x512 pixels, was used for the experiments. The watermark is taken from the logo of King Mongkut’s Institute of Technology Ladkrabang (KMITL) which is a binary image of size 128x128 pixels. Fig. 5(a) shows the color-composite of the original multispectral image along with the KMITL’s logo. The watermarking is tested with the following parameters: the magnitude factor is 35, the key is 500. The result of the watermarked image and the extracted watermark are shown in Fig. 5(b). The PSNR of the resulted image is equal to 41.42 dB.

![Fig. 5](image)

(a) Original image and the signature image. (b) Watermarked and extracted watermark images.

(PSNR = 41.42 dB, NC = 0.9503)

The robustness capability is very critical for watermarking. We tested the robustness of watermarking with some attacks such as median filter, Gaussian noise and JPEG compression. Fig. 6 and 7 shows the results of watermark detection after smoothing with 3x3 median filters and JPEG compression with quality factor 80%. The robustness against Gaussian noise is illustrated in Fig. 8.

![Fig. 6](image)

Watermarked image smoothed with a 3x3 median filter and the extracted watermark images

(PSNR = 36.69 dB, NC = 0.7850)
5. Conclusion

In this paper, we have presented a digital watermarking technique where a binary image can be used as a watermark. The proposed method is archived by applying a wavelet-based watermarking technique on the most principal component image resulted by the KLT. The robustness against various attacks such as smoothing with 3x3 median filter, JPEG compression, and Gaussian noise are also presented. In all cases, the watermark can be detected with an acceptable visual quality.

References