ADAPTIVE DIGITAL IMAGE WATERMARKING USING VARIABLE SIZE OF BLOCKS IN FREQUENCY DOMAIN

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Abstract
An adaptive digital image watermarking system considering of the human visual system (HVS) is presented in frequency domain. The digital watermarks are embedded in selected discrete cosine transform (DCT) coefficients of variable size of blocks. To accommodate the HVS characteristics, the image is divided into variable size of blocks, where each block contains only homogeneous region. The watermark is inserted by significantly changing the selected DCT coefficients of the block that has great variance or by slightly changing for the stationary block. It is shown that the proposed method has good robustness against several image processing operations without significant degradation of image quality by simulation using various test images.

I. INTRODUCTION

The success of the network infrastructure and many digital image authoring/processing technologies has created a pressing need for the protection of copyright ownership in high quality multimedia content. For this reason, digital watermarking for image, video, audio, and other multimedia contents, has drawn extensive attention in recent year.

The digital watermarking, in short, is imperceptible marking of multimedia data by modification of original contents to insist ownership. Until now, there are many watermarking algorithms have been developed. These techniques embed watermark signal in spatial domain [1,2,3] or transform domain, especially, DCT or wavelet transform [4,5,6]. Some of these techniques embed the white noise type of watermark, some other techniques use binary sequences for watermark.

There are some requirements for watermarking algorithm to be used for copyright protection. Most of all, robustness and imperceptibility are basic requirements. Robustness means that the embedded watermark in host image must persist after several types of attack. Invisibility means that embedded watermark must not make visual artifact in host image. There are several types of attack such as blurring, sharpening, geometric image processing, compression, A/D, D/A converting, etc. For robustness, much of the host image must be modified, but this make serious degradation of image quality. For this reason, modification of image without perceptual artifact is important. This can be achieved using the characteristics of human visual system.

In this paper, we propose an adaptive digital image watermarking in discrete cosine transform (DCT) domain based on visual characteristics to get more robustness against several image processing algorithms without great degradation of image quality. In our method, the original image is divided into variable size of blocks using region split algorithm [7], and pseudo random binary sequence is embedded to each block according to its block activity. Using this scheme we can reduce the block artifact caused by embedding of watermark.

In the next section we explain the proposed watermarking algorithm. In section III, we provide experimental result for proposed algorithm. By comparison of original image and watermarked image, the imperceptibility of proposed technique is shown. The robustness of the proposed algorithm is shown by watermark detector response after several image processing operations that are applied to watermarked image. In section 4, conclusion and discussion are provided.

II. METHODS
In this section we explain our approach for insertion and detection of the watermark.

Generally, human eye is more sensitive to change in simple region of image than change in complex region and also more sensitive to change of low frequency element. Using this property, we propose new watermarking which adaptively adjusts the image modification level according to the region activity and the frequency coefficient values. In proposed scheme, image is segmented into variable size of blocks according to region activity. Active region is segmented into small blocks and changed much. Inactive region is segmented into larger blocks and changed little. As a result the visual artifact by watermarking is minimized. Proposed method embed watermark signal into frequency domain, because it is more robust to several attacks and naturally adjust to image compression standard such as JPEG.

A. The Architecture

Embedding procedure consists of several operations as in Fig. 1. Firstly, original image is segmented into variable size blocks that contain homogeneous pixels. Secondly, block DCT is performed to each block. Thirdly, coefficients in each DCT block are modified according to the binary watermark signal. The number of coefficient and the changing amount are decided by the block activity and each coefficient value. Lastly, watermarked image is created by inverse block DCT of the modified coefficients.

B. Image Segmentation

As explained above, for watermark embedding, entire image is segmented into several blocks with variable size according to their block activity. The proposed algorithm uses region split algorithm [7] for image segmentation. Segmentation process is performed as:

1. For each block (initially entire image) do 2–4.
2. Calculate the block activity.
3. If the block activity is lower than certain threshold or the block size is smaller than predefined minimum block size, then the stop segmentation of the block. Otherwise the block is segmented into sub-blocks with same size.
4. Repeat 2–4 for each sub-block.

After this process, the image is segmented into variable size blocks that consist of homogeneous pixels or have predefined minimum block size.

In the segmentation process, several factors such as variance, spectral energy in transform domain can be considered for block activity measure. Equation (1) shows the variance of k-th block. In this equation, \( \mu \), \( x_k(i) \) and \( n \) mean the mean of block, i-th pixel in the block, and number of pixels in the block respectively. Equation (2) shows the spectral energy of the block in transform domain. In this Equation \( X_k(i) \) means the i-th coefficient in the transform domain.

\[
A_k = \frac{\sum_{i=1}^{n} (\mu - x_k(i))^2}{n - 1} \quad (1)
\]

\[
A_k = \frac{\sum_{i=1}^{n} X_k(i)^2}{n} \quad (2)
\]

Our approach uses variance for block activity measure because of following reasons: (1) Computation complexity is much lower than that of spectral energy and (2) there is little difference between segmentation results using two activity measure.

C. Watermark Embedding

After the block segmentation, watermark is embedded into each block. Firstly, each block is transformed using DCT. In each transformed block, some coefficients are selected and changed according to watermark bit information. For invisibility the modification amount is adjusted by the activity of the block and the magnitude of selected coefficient. The coefficients that have large magnitude and belong to the block with large variance is changed more. For watermark signal binary pseudo random sequence is used and bi-directional coding is used for watermark embedding.
The high order coefficient is vulnerable to several types of image processing, such as blurring, sharpening, noise addition and image coding. So, the lower or middle band coefficient is target of watermark embedding. As shown in Fig. 2, only upper left coefficients in gray area are changed during watermark embedding.

![Fig. 2. Watermark Embedding Region in 8x8 block](image)

Because human eye is more sensitive to change in lower frequency components, not all coefficients in lower and middle band are changed. Using some criteria, appropriate coefficients are selected. In our approach, only the coefficients that have high energy are modified. The coefficients of which energy is higher than the average energy of coefficients in gray area are changed for watermark embedding. Coefficient modification is done as equation (3) and (4).

\[
\text{Coef}^* = \text{Coef} + \alpha \times \text{Coef} \times \log A \quad \text{(when bit = 1)} \quad (3)
\]

\[
\text{Coef}^* = \text{Coef} - \alpha \times \text{Coef} \times \log A \quad \text{(when bit = 0)} \quad (4)
\]

In equation (3) and (4), Coef and Coef* mean coefficient of original block and corresponding modified coefficient respectively. The \(\alpha\) means watermark embedding strength and the \(A\) means that the block activity. Using this equation the changing level of coefficient is adjusted by block activity and the coefficient energy. For example, if the block activity is high and the magnitude is high, then the modification level is high.

### D. Detection

Original image is used for watermark detection. As in the embedding process, original image and watermarked (possibly corrupted) image is segmented using region split algorithm. Bit extraction is done as equation (5). In equation (5), all symbols have same meaning with equation (3), (4). The \(\beta\) is lower value constant than the \(\alpha\). Extracted watermark signal is compared with the original watermark, and the radio of same bit is used for the watermark detection measure.

\[
\text{Extracted Bit} = \\
\begin{cases} 
1 & \text{if } |\text{Coef}^*| > |\text{Coef}| + \beta \times |\text{Coef}| \times \log A \\
0 & \text{if } |\text{Coef}^*| < |\text{Coef}| - \beta \times |\text{Coef}| \times \log A
\end{cases} \quad (5)
\]

### III. RESULTS

In this section the experimental result is provided. We used Lena image for the experiment. Firstly, we tested detector response for watermarked image using about 1000 different watermark sequence without any image processing. For robustness test, we performed several image processing such as blurring, sharpening and JPEG compression. After image processing performed, the detector response for embedded watermark and other watermarks is tested.

Fig. 3 shows original image and watermarked image. As shown in the figure, it is difficult to distinguish two images. Fig. 4 shows the detector response (bit matching ratio) to 1000 random watermark sequence. In this figure, detector response has highest value (0.995) only for embedded watermark and about 0.5 for the other watermarks. Because the embedded watermark is binary random sequence, it is natural that other sequences have about 0.5 for detector response.

![Fig.3 Comparison of original image and watermarked image (a) Original Image and (b) Watermarked Image](image)

![Fig.4. Detector response (bit matching ratio) to 1000 randomly generated watermarks](image)

Fig. 5 and 6 show the detector response for watermarked image after blurring and sharpening respectively. In Fig. 5 and 6, the detector response to embedded watermark is relatively lower than in Fig 4, but definitely higher than for other watermarks. Using appropriate threshold embedded watermark can be detected without confusion in these cases.
Table 1. Detector Response under JPEG Lossy Compression

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<tbody>
<tr>
<td>Matching Ratio</td>
<td>0.935</td>
<td>0.873</td>
<td>0.838</td>
<td>0.785</td>
<td>0.759</td>
<td>0.724</td>
<td>0.694</td>
<td>0.635</td>
<td>0.581</td>
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achieved without great image quality degradation.

REFERENCES


In table 1, detector response after JPEG lossy compression is shown. As in the table, the higher compression ratio, the lower detection response is. Supposing the response to not embedded watermark is about 0.5, the embedded watermark survive to about 16:1 compression.

IV. CONCLUSION

In this paper we proposed a new block based watermarking algorithm in which the blocks is decided as variable size according to block activity. For high activity region large block is allocated and for low activity region small block is allocated. Watermark embedding is performed in DCT domain. Using block activity and coefficient energy, the modification of coefficients is controlled. By doing this, the robust watermarking is