Abstract—This paper presents an image watermarking method where partial embedding approach is implemented in order to avoid interference from other nearby watermark bits. With cautious selection of watermark embedding positions, the maximum number of embedding bits can also be achieved. Precisely, the embedding positions are pseudo-randomly selected from the blue component of the host color image in accordance with a secret key, while the watermark extraction is blindly achieved by using pixels around the embedding bit in the same position and sequence used in the embedding process. The experimental results verify the better performance in term of accuracy of the extracted watermark compared to the previous related work [3].

Keywords—image watermarking, partial embedding, extracted watermark

I. INTRODUCTION

Most information in the form of digital media e.g. audio, video and images can be rapidly distributed all over global networks. To prevent people from misusing the media of the others i.e. by distributing the illegal made copies to their friends and even to the public, which lead to copyright related problems, digital watermarking technique is considered and introduced. Digital watermarking is a technique used to embed secret information called “watermark” in to host digital media before distributing it to the public while quality degradation of the watermarked media is unnoticeable by human eye. Since the embedded watermark still exist within the new copies of that watermarked media, the watermark inside can then later be recovered, and used to verify the real owner of such media. However, some noises and attacks can be introduced unintentionally and/or intentionally. Therefore, a decent watermarking method should be robust against all possible noises and attacks.

Presently, a large number of image watermarking methods have been proposed and proved to be robust against various kinds of noises and attacks. In spatial domain based approach, it is obvious that the processes of watermark embedding and extracting are simple to perform by directly modifying the host media, e.g. image pixels. In 1998, M. Kutter et al. [1] proposed an image watermarking method base on amplitude modulation. Their method was proved to be robust against various types of attacks including JPEG compression standard. The method embedded a watermark bit into an image pixel by modifying that pixel using either additive or subtractive depending on the watermark bit, and proportional to the luminance of the embedding pixel. According to their method, the blue color channel was selected to carry the watermark bit since it is the one that human eye is least sensitive to. The watermark extraction was achieved, without the need of original image, by using a prediction technique based on a linear combination of pixel values in a cross-shape neighborhood around the embedded pixels. To improve the watermark extraction performance, T. Amornraksa et al. [2] proposed some techniques to enhance its watermark extraction performance by balancing the watermark bits around the embedding pixels, tuning the strength of embedding watermark in accordance with the nearby luminance, and reducing the bias in the prediction of the original image pixel from the surrounding watermarked image pixels. The probability to extract the watermark will be increased. They also demonstrated how to embed a watermark image (logo) into a color image having the same resolution as well. However, the accuracy of the original image pixel prediction decreases due to the high variance image pixel values contained within such particular type of image. In 2009, C.-H. Lai et al. [3] proposed image watermarking method based on multi-scale neighbourhood-matching which is robust to local geometric distortions. Their method used the standard deviation of the neighbourhood to determine the existence of the embedded watermark and then using the average of the neighbourhood for extracting the watermark. Although this method achieved a high quality of the extracted watermark, it provided a watermark capacity of approximately 12% of the number of host image pixels. Recently, K. Thongkor et al. [4] proposed a digital image watermarking for camera-captured image contained glass reflection, where the same concept of watermarking algorithm in [2] was extended to cover some problems in practical watermarking application i.e. the image registration technique based on projective transformation was applied to the distorted image in order to diminish both RST and perspective distortions caused by the printing and camera-capturing processes.

In this paper, we propose an image watermarking with partial embedding on blue component of a host color image.
We modified the concept of spatial domain color image watermarking used in [1]-[4] in order to achieve a better performance in term of accuracy of the extracted watermark. The next section presents some background of the spatial domain image watermarking, while our proposed method based on the concept of partial embedding is introduced and described in section 3. In section 4, the experimental results are shown and discussed, and section 5 draws the conclusion.

II. BACKGROUND OF THE WATERMARKING METHOD [4]

The watermark embedding is performed by modifying the blue component at a coordinate \((i,j)\), in a line scan fashion left to right, top to bottom. The modifications of the blue component in each pixel \(B(i,j)\) are either additive or subtractive, depending on \(w(i,j)\), and proportional to the luminance of the embedding pixel \(L(i,j) = 0.299R(i,j) + 0.587G(i,j) + 0.114B(i,j)\). The watermark embedding and extraction methods can be shown as the equations below.

\[
B'(i, j) = B(i, j) + w(i, j)sL(i, j)
\]

\[
w'(i, j) = \frac{1}{8} \left[ \left( \sum_{m=-1}^{1} \sum_{n=-1}^{1} B'(i + m, j + n) \right) - B'(i, j) \right]
\]

where \(B'(i, j)\) is a watermarked pixel around \((i,j)\). \(w'(i,j)\) is an estimation of \(w(i,j)\). To analyze factors that affect the estimation of \(w(i,j)\), Eq. (2) is rewritten by

\[
w'(i, j) = \frac{1}{8} \left( \sum_{m=-1}^{1} \sum_{n=-1}^{1} B(i + m, j + n) \right) - B(i, j)
\]

The first and second terms in the right-hand side of Eq. (3) represent the original pixel value and the watermark at \((i,j)\), while the third and fourth terms represent the prediction of \(B(i,j)\) and the summation of watermark around \((i,j)\), respectively. We can see that the watermark at \((i,j)\) can be recovered back if the first term equals the third term, and the fourth term equals zero.

III. PROPOSED METHOD

Based on the above analysis, with a lower number of biased pixels, i.e. the watermarked pixels, the accuracy of the extracted watermark should be improved. Therefore, instead of embedding watermark the whole image same as method in [4], we propose to select positions to embed the watermark for fidelity reason as 25 percentage. That means the number of biased pixels used in the original prediction process will be reduced by quarter, e.g. from four pixels to one pixels. Below is the detail of our proposed method.

A. Watermark Embedding Process

We select positions for embedding the watermark to reduce number of biased pixel and avoid disturbing from the neighbors watermarked pixels. The embedding positions are randomly selected according to secret key for the security reason. Detail for selecting the embedding positions is described as follows. Firstly, an empty pane which is same size as original host image is created and then it is divided into block of 4x4 pixels. Each block is randomly selected nonadjacent 4 positions for embedding watermark. After that, each agent of each block will be checked its surrounding positions to decide whether this position is selected to embed watermark. If its surrounding positions were not selected yet, this position will be selected. Otherwise, shift to the right hand side 1 position and then checked its surrounding positions again. Finally, a location map where the watermark has been embedded, embedPane(i,j) is obtained. Flow chart of selecting embedding positions for each block is shown in Fig. 1.

Fig. 1. Flow chart of embedding position selector block

The watermark logo, \(I_w(i,j)\) is created using only two colors: black (0) and white (1). The watermark bits are first permuted by using Gaussian distribution to disperse bits 0s and 1s. The numbers of bit 0 and 1 are balanced by XORing the result with a pseudo-random bit stream generated from a key-based stream cipher. This key-based stream cipher is considered and used for security purpose as well. Note that in the exclusive or (XOR) operation, the value of -1 is considered as 0. Finally, bits 0s are converted into -1 and reshaped to one dimension, so that the watermark to be embedded become as \(w(k) \in \{-1,1\}\) where \(k = m \times n \times m\) and \(n\) are the numbers of row and column in the watermark logo, respectively. The watermark embedding is performed by modifying the image pixel in blue component of the host image, \(B(i,j)\) in a line scan fashion, left to right and top to bottom. Since blue component is least sensitive to human eyes, it is used to carry watermark.
The modification of image pixel \( B'(i,j) \) are modified either additive or subtractive, depending on \( B(i,j) \), \( w(k) \), signal strength \( s \), embedPane\((i,j)\) and proportional to the luminance component of each embedding pixel, \( L(i,j) = 0.2999 R(i,j) + 0.587 G(i,j) + 0.114 B(i,j) \). The embedding equation is represented by

\[
\begin{align*}
\text{If embedPane}(i,j) = 1 & \quad B'(i,j) = B(i,j) + w(k) \cdot s \cdot L'(i,j) \\ \text{Otherwise} & \quad B'(i,j) = B(i,j)
\end{align*}
\] (4)

And the minimum and maximum values of watermarked component are bounded by

\[
\begin{align*}
B_{\text{min}}(i,j) &= \frac{1}{8} \left[ \sum_{m=-1}^{1} \sum_{n=-1}^{1} B(i + m, j + n) - B(i,j) \right] - s \cdot w(k) \cdot L'(i,j) \\
B_{\text{max}}(i,j) &= \frac{1}{8} \left[ \sum_{m=-1}^{1} \sum_{n=-1}^{1} B(i + m, j + n) - B(i,j) \right] + s \cdot w(k) \cdot L'(i,j)
\end{align*}
\] (5) (6)

where the modification of luminance component \( L'(i,j) \) is obtained from a Gaussian pixel weighting mark to help improve the overall performance.

**B. Watermark Extraction Process**

The watermark extraction is achieved by using a prediction technique. It uses surrounding neighborhoods with its as shown in the following equation.

\[
B^*(i,j) = \frac{1}{8} \left[ \sum_{m=-1}^{1} \sum_{n=-1}^{1} B'(i + m, j + n) - B'(i,j) \right]
\] (7)

where \( B^*(i,j) \) is a prediction of original blue pixel \( B(i,j) \). After that, the estimation of the embedded bit \( w'(i,j) \) at \( (i,j) \) can be obtained by the following equation.

\[
w'(k) = B'(i,j) - B^*(i,j); \text{ if embedPane}(i,j) = 1
\] (8)

where embedPane\((i,j)\) is generated using secret key to find which pixels are embedded watermark same as the location map in the embedding process. After that \( w(k) \) is reshaped to two dimensions become as \( w'(i,j) \). Since \( w'(i,j) \) can be either positive or negative, the zero value set as a threshold, and its sign is used to estimate the value of \( w(i,j) \). That is, if \( w'(i,j) \) is positive (or negative), \( w'(i,j) \) is estimated as 1 (or -1, respectively). Notice that the magnitude of \( w'(i,j) \) reflects a confident level of estimating \( w(i,j) \). Finally, the bits -1s of \( w'(i,j) \) is converted into 0, and the result is XORed with the same pseudo-random bit stream, as used in the embedding process and then the result is passed to invert permutation to obtain the extracted watermark image \( I_w(i,j) \in \{0,1\} \).

**IV. EXPERIMENTAL SETTING AND RESULTS**

In all experiments, eight color images with size 256x256 pixels, including ‘lena’, ‘house’, ‘peppers’, ‘f16’, ‘splash’, ‘lake’, ‘tiffany’ and ‘tree’ were used as the original host images. All of them were taken from [7]. Additionally, a two-tone black and white color image with size 127x127 pixels was created and used as a watermark logo.

In this paper, Peak Signal-to-Noise Ratio (PSNR) is employed to measure the quality of watermarked image compared with original host image. PSNR is a common objective quality measure for evaluating the quality of watermarked image. Beside, Normalize Correlation (NC) is employed to measure the accuracy of the extracted watermark. Note that the NC value varies between 0 and 1. NC value as unity indicates the two compared watermarks are identical while NC value as zero indicates that the two compared watermarks are totally different. Also, a higher NC value indicates more accurate the extracted watermark.

Firstly, the PSNR value that gives a perfect extracted watermark, i.e. the NC value of 1 was attempted to determine. Since the extracted watermark can be blindly estimated, the prediction of \( B \) component in the extraction process might incorrect. Therefore, the highest NC value experimentally achieved from our proposed method was greater than or equal to 0.995. Table 1 shows the highest PSNR value of each original host image compared to previous related watermarking method [3] and shows the capacity of each original host image. Note that method [3] can resist local geometric distortions if watermark resynchronization by image registration is performed. It was proposed and used to correct local geometric distortions before extracting watermark. Since in this paper, we proposed watermark embedding and extraction algorithm, we compared our method with method [3] except performing its watermark resynchronization process to make a fair comparison and we evaluated their performance against general attacks in next experiment.

Next, we evaluated the robustness of the embedded watermark by applying different types of attack at various strengths to the watermarked images obtained from the two methods at the PSNR of 35±0.1 dB. Note that the method in [3] extracted the watermark from the attacked image by exploiting the embedding mask which indicates the embedded positions. Five types of attacks we considered and used in the experiments were salt & pepper noise at various densities ranging from 0.01 to 0.06, contrast adjustment at various scaling factors ranging from 1 to 2, brightness enhancement at various percentages ranging from 10 to 100%, rescaling at various ratios ranging from 0.75 to 2, and image blurring at
various pixel values ranging from 2 to 20 pixels. The plots of
the average NC values of the extracted watermarks from the
two methods, after being attacked, are shown in Fig. 3. 
Obviously from all figures, the proposed method was superior
to the previous one, judged from a higher average NC value at
the same PSNR.

**TABLE I. PSNR VALUES OF EACH WATERMARKED IMAGE WHICH CAN BE 
ESTIMATED UNDER NO ATTACKS AND THEIR CAPACITIES AT NC = 1**

<table>
<thead>
<tr>
<th>Color images</th>
<th>Previous method [3]</th>
<th>Proposed method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixels 256x256</td>
<td>PSNR</td>
<td>Capacity</td>
</tr>
<tr>
<td>lena</td>
<td>38.61</td>
<td>8490</td>
</tr>
<tr>
<td>house</td>
<td>39.87</td>
<td>6664</td>
</tr>
<tr>
<td>f16</td>
<td>37.67</td>
<td>9963</td>
</tr>
<tr>
<td>peppers</td>
<td>39.36</td>
<td>7096</td>
</tr>
<tr>
<td>splash</td>
<td>36.88</td>
<td>12039</td>
</tr>
<tr>
<td>lake</td>
<td>39.49</td>
<td>6798</td>
</tr>
<tr>
<td>tiffany</td>
<td>38.40</td>
<td>8747</td>
</tr>
<tr>
<td>tree</td>
<td>40.83</td>
<td>4838</td>
</tr>
<tr>
<td>Average</td>
<td>38.89</td>
<td>8004</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Brightness enhancement</th>
<th>Previous method [3]</th>
<th>Proposed method</th>
<th>16129</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor (a)</td>
<td>1</td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>Factor (b)</td>
<td>1.5</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>Factor (c)</td>
<td>2.5</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Factor (d)</td>
<td>3.5</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Factor (e)</td>
<td>4.5</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

![Fig. 3. The average NC values of the extracted watermarks from the two
methods, after being attacked, i.e. (a) salt & pepper noise at various densities,
(b) contrast adjustment at various scaling factors, (c) brightness enhancement
at various percentages, (d) rescaling at various ratios, and (e) image blurring at
various pixel values, respectively.](Image)

![Fig. 4. (a)-(e) Extracted watermark from the previous method [3] and
(f)-(j) extracted watermark from the proposed method](Image)

**V. CONCLUSION**

In this paper, we have presented an image watermarking
method applying the concept of partial watermark embedding.
The experimental results showed the improvements in both
accuracy of the extracted watermark and robustness of the
embedded watermark against attacks, compared to [3].

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