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An Embedding and Detection Method of Invisible Calibration Pattern for Print-Type Data Hiding

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Abstract—In the print-type steganographic system and watermark, a calibration pattern is arranged around contents where invisible data is embedded, as plural feature points between an original image and the scanned image for normalization of the scanned image. In this paper, we propose an arrangement and detection method of an invisible calibration pattern based on the characteristics of human visual perception. The most important part of human visual perception in the proposed method is the spectral luminous efficiency characteristic and the chromatic spatial frequency characteristic. We embed the calibration pattern in an original image by adding high frequency component to blue intensity in a limited region. It is suggest that the proposed method protect page layout and artwork of original contents.

1. Introduction

Recently year, a print-type steganographic system and a watermarking technique had been widely studied by the improvement of scanning devices such as a digital scanner and a digital camera [1]-[6]. A basic concept of these methods is to embed invisible data into printed images and documents. Those printed contents are distributed widely, and it is used for security and internet services. In the digital watermarks system, embedding data is used for copyrights protection. On the other hand, print-type steganographic technique is one of data hiding method, does not reduce image quality. Moreover, it does not interfere with page layout and artwork.

Generally, when a printed image is converted from analog data to digital data by using the scanning device, the scanned image is influenced by geometrical transform, light source, noise and so on. Therefore, in order to normalize the scanned image, it is necessary to detect plural feature points which are one to one corresponding points between an original image and the scanned image. In the conventional method, many kind of calibration pattern have been proposed to represent these feature points. To take an example of typical calibration pattern, visible calibration patterns were set to four corners of contents. Nakamura set a black border to the surroundings of contents [4]. In [5], visible calibration patterns are arranged around contents where invisible data is embedded. On the other hand, shape and background color of contents is restricted to simplify extraction of region where invisible data is embedded [6]. Hence, it is clear that conventional methods interfere with page layout and artwork of contents.

In this paper, we propose an arrangement and detection method of an invisible calibration pattern based on characteristics of human visual perception. The most important part of human visual perception in the proposed method is the spectral luminous efficiency characteristic and the chromatic spatial frequency characteristic. The calibration pattern is embedded to blue intensity in an original image by adding high frequency component. It is difficult to perceive the embedded calibration pattern by the effects of the human visual perception characteristic. In addition, background in the surrounding of contents is not restricted to uniform color. It is suggest that the proposed calibration pattern protects page layout and artwork.

2. The characteristics of visual perception

A human recognize electromagnetic waves whose wavelength is 360 - 800 [nm] as rays of light. Then, human perceives color when signal is transmitted from a visual cell to a brain. Under bright light condition, a cone operates actively compared with a rod cell. Sensitivity of blue light in the human visual characteristic is lower than other color. By the way, when human see a periodic stimulation pattern, the spatial frequency characteristic in the human visual characteristic is defined to the threshold of contrast. In other words, it is frequency characteristic of sensitivity which is defined by the inverse of the threshold. Generally, it is difficult for human to perceive pattern which changes cyclically at high frequency. The example of chromatic

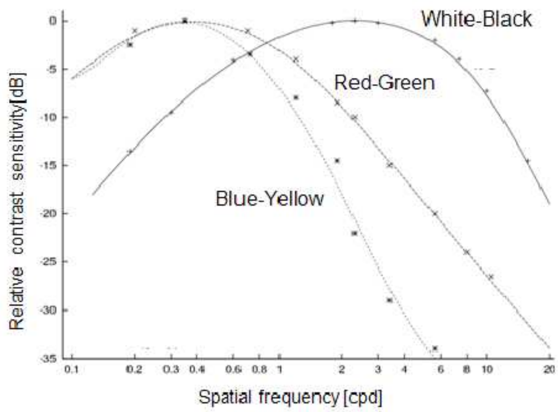

Figure 1: The example of chromatic and brightness spatial

Figure 2: The spatial frequency characteristics

and brightness spatial frequency characteristics of the visual system is shown in Fig. 1 [7]. For instance, when human see a periodic stimulation pattern which was constructed by two colors, there is a possibility that human perceive other color. In the high frequency domain of the pattern such as Fig. 2, it is perceived as uniform gray by influence of the spatial frequency characteristic.

3. Proposed Method

3.1. Pattern template

In this paper, we propose a new digital template to set the invisible calibration pattern. The 2-dimensional template is created based on Eq. 1, and the detail of the template is shown in Fig. 3.

$$template(x, y) = \alpha * cos\frac{\pi}{\beta}\sqrt{x^2 + y^2} * e^{\gamma\sqrt{x^2+y^2}} \quad (1)$$

The cyclical structure of this template is defined concentrically on the basis of center of template. In Eq. 1, the parameter α means the maximum amplitude of template, the parameter β means a period. The parameter γ means damping. The origin of template is the central part of template. In the origin, the template has the maximum amplitude.

3.2. Embedding of calibration pattern

In order to embed the invisible calibration pattern in an original image, coefficients of defined template are

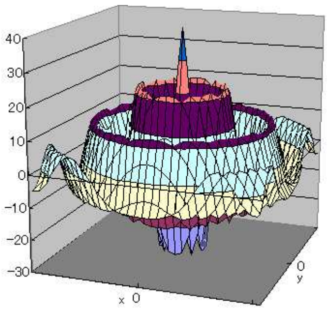

Figure 3: The sample of template

added to blue component of each pixel. The reason why the blue component is changed is that sensitivity of blue light is lower than other light in the human visual characteristic. In order to embed the calibration pattern in point (x, y), the blue component in the range of $(-\frac{fs}{2} < i, j < \frac{fs}{2})$ is operated based on the following equation.

$$T_B(x+i, y+j) = I_B(x+i, y+j) + template(i, j) \quad (2)$$

The parameter fs means width of the proposed template. The $I_B(x, y)$ is blue intensity of point(x,y) in the original image. The $T_B(x, y)$ is blue intensity of embedded image. Generally, the BMP image is defined as 24 [bit] based on RGB color image, and each intensity value is shown by 8[bit]. If the template which has high amplitude is used for the embedding of calibration pattern, there is a possibility that the blue component of calibration pattern in the embedding image is not expressible by 8 [bit]. For this reason, if the pixel not expressible by 8 [bit] is conformed when the proposed template was embedded in the original image, the maximum excess value is operated based on the following equations. The parameters i and j ranges from $(-\frac{fs}{2} < i, j < \frac{fs}{2})$.

$$E_u(x, y) = \max_{-\frac{fs}{2} \le i,j \le \frac{fs}{2}} \{T_B(x+i, y+j) - 255\} \quad (3)$$

$$E_l(x, y) = \max_{-\frac{fs}{2} \le i,j \le \frac{fs}{2}} \{0 - T_B(x+i, y+j)\} \quad (4)$$

$$T_B(x+i, y+j) = \begin{cases} T_B(x+i, y+j) - E_u(x, y) & (E_u > 0) \\ T_B(x+i, y+j) + E_l(x, y) & (E_l > 0) \end{cases} \quad (5)$$

However, if the calibration pattern was embedded in region which has blue intensity with variation, it is difficult to detect the pattern embedded in the normal background image, since an embedded pattern had lost defined shape by influence of original background.

To avoid decrease of detection accuracy, we propose the improvement of embedding method. The procedure included the following step: firstly, the calibration pattern is temporarily embedded in point (x, y) of the original image. Then, the Normalized Cross Correlation (NCC) on target pixel (x, y) is calculated. If $NCC(x, y)$ is less than defined threshold T, the blue intensity of the original image is smoothed to avoid decrease of detection accuracy. The blue component in the range of $(x-\frac{fs}{2} < a < x+\frac{fs}{2}, y-\frac{fs}{2} < b < y+\frac{fs}{2})$ on the basis of point (x,y) is operated based on the following equation.

$$I_B(a,b) = \frac{1}{ws^2} \sum_{j=-\frac{ws}{2}}^{\frac{ws}{2}} \sum_{i=-\frac{ws}{2}}^{\frac{ws}{2}} I_B(a+i, b+j) \quad (6)$$

In this equation, the parameter ws means the range of smoothing filter. Finally, to ascertain whether the similarity $NCC(x, y)$ is higher than the threshold, the calibration pattern is temporarily embedded. If similarity is less again, the smoothing is carried out several times. As a result of this smoothing, it is confirmed that image quality does not deteriorate by influence of human image perception.

3.3. Detection of Calibration Pattern

Conventionally, the NCC is used for a detection method of proposed calibration pattern [8]. The NCC is robust for linear changing of brightness and additive noise. However, the detection using the NCC requires a lot of time.

Thus, in order for the detection of calibration pattern to achieve high-speed and high accuracy processing, the detector composed of three kinds of brief weak classifiers is proposed. The new similarity $R(x, y)$composed of some brief weak classifiers is shown in Eq. (7) .

$$R(x,y) = \frac{\sum_{i=0}^{fs-1} (w_i D_{1(i)} D_{2(i)})}{\sum_{i=0}^{fs-1} w_i}(a-1) + \sum_{k=0}^{a-1} D_{3(k)} \quad (7)$$

$$w_i = template(-\frac{fs}{2}+i, 0), \quad v_i = T_B(x-\frac{fs}{2}+i, y) \quad (8)$$

The target pixel for the calculation is restricted in the direction of one-dimensional. The weak classifier $D_{1(i)}$ estimate the direction of gradient of pixel value, which is represented by:

$$D_{1(i)} = \begin{cases} 1 & \text{If the sign of } W_i \text{ and } V_i \text{ is the same} \\ 0 & \text{otherwise} \end{cases} \quad (9)$$

where W_i means $w_{i+1} - w_i$, and V_i means $v_{i+1} - v_i$. The weak classifier $D_{2(i)}$ estimate the difference pixel value between target pixel and neighboring region.

(a) The uniform image (b) The normal image

Figure 4: The sample of test image

$$D_{2(i)} = \begin{cases} 1 & \text{If } |V_i| < M \\ 0 & \text{otherwise} \end{cases} \quad (10)$$

The threshold M is defined from shape of the embedded pattern. The weak classifier $D_{3(i)}$ judge the direction of damping by using the extreme value.

$$D_{3(k)} = \begin{cases} 1 & \text{If } u_k < u_{k+1} \quad (k < \frac{a-1}{2}) \\ & \text{or } u_k > u_{k+1} \quad (k > \frac{a-1}{2}) \\ 0 & \text{otherwise} \end{cases} \quad (11)$$

In the Eq.(7), the parameter a is same as the number of extreme value of proposed template. The parameter u_k means absolute value of difference between each extreme value.

4. Evaluation

4.1. Experimental Condition

We use 25 images including a landscape, a portrait and an illustration for evaluation. The size of original images is 256×256 [pix.] and these are 24 [bit] RGB color. The blank space of about 50 pixels is provided to the surrounding of original image. The test data for the simulation is composed of a uniform background image and a normal background image. In the uniform background image, a color based on two colors which were selected at random is painted on the blank space. The sample of these images is shown in Fig. 4. The calibration patterns are embedded in four regions shown by green line. Experimentally, the embedded pattern has each parameter $\alpha = 40$, $\beta = 2.0$, $\gamma = -0.1$, $ws = 5$, $T = 0.25$. In addition, the size of calibration pattern is set to 31 [pix.].

Moreover, we use two type of scanning devices, the digital scanner (CANON F5400) and digital camera (CANON PowerShot S3 IS). The resolution for scanning is 150 [dpi] and 600[dpi.], respectively.

4.2. Evaluation of detection

In this simulation, we evaluate the combination of brief weak classifiers for stable detection of calibration

Table 1: The detection result using each parameter (detection rate [%])

Background	Uniform			Normal		
Case	1	2	NCC	1	2	NCC
Scanner	100	100	100	86	83	100
Camera	74	55	97	60	35	73

pattern. The results of pattern detection is shown in Tab. 1. As the case 1, the similarity is composed of only weak classifiers (D_1, D_2) for estimation of the periodicity. As the case 2, the similarity includes all weak classifiers. The similarity $R(x, y)$ is calculated from horizontal and vertical pixels on the basis of target pixel. For the purposes of comparison of proposed similarity with conventional method, we show the detection accuracy using the NCC. From this result, the detection rate in the proposed similarity is lower than the conventional method.

To evaluate the performance of execution time, we implemented it with the support of the Intel OpenCV library using a PC with Microsoft Windows XP SP3. The hardware platform for the experiment is a PC equipped with an Intel Core 2 Duo 2.8GHz CPU and 2GB RAM. As a result, execution time of case 2 is 11.8 [ms], execution time of the NCC is 223.8 [ms].

In order to improve the detection accuracy, the region for calculation of similarity is expanded. The extended regions consists of a diagonal lines and four lines adjoining lines defined previously. As a result, detection rate in the uniform background is 98[%], and the normal background is 83[%]. On the other hand, execution time is 50.8 [ms]. Therefore, it is confirmed that the detection accuracy and execution time of proposed method is sufficient compared with conventional method.

4.3. Evaluation of invisibility

In order to show the evaluation of invisibility, we performed the subjectivity experiment based on the single-stimulus methods. In this experiment, one calibration pattern is arranged to the normal background image at random. On the other words, the proposed pattern is not embedded in three other corners. We show some test images to 9 test subjects. The test subject answers to the question where pattern was embedded. As one measure of the performance of invisibility, we require detection accuracy and time for questions to get answered. The parameters of arranged pattern are α=40, $\beta = \{2.0, 3.0\}$, $\gamma = -0.1$. The resolution for printing is 150 [dpi]. The distance between printed paper and test subject's eye is restricted to 30 [cm].

As a result of subjective experiment, detection rate is 16.6[%], and response time is 8.3[s]. On the other hand, when the periodic parameter is $\beta = 3.0$, each result are 22.2[%] and 7.1[s]. From these results, invisibility of proposed pattern is high.

5. Conclusions

In this paper, we proposed the embedding and detection method of invisible calibration pattern based on the human visual perception. In order to show the effectiveness of proposed method, we revealed the relation between pattern parameters and detection accuracy. In addition, we performed evaluation of visibility in the proposed method by subjective experiment.

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