# A Geometric Compensation Method for Image Watermarking Schemes and Its Required Accuracy

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## Abstract

*This paper proposes a geometric compensation method for improving the watermark extraction ability. The proposed method is independent of watermarking schemes, whereas the conventional approach makes the particular watermarking scheme resistant to geometric deformation. The proposed method estimates geometric parameters by phase-only correlation technique using the original image rather than the stego image in which watermark is hidden. The required accuracy for geometric estimation is investigated by computer simulation, and performances are evaluated using real printed-and-scanned images.*

**keywords:** Data hiding, Printing-and-Scanning, Compensation order, RST-invariant

## 1. Introduction

Digital watermarking technology has been diligently studied, for not only security-related problems [1] but also non security-oriented [2, 3]. A digital watermarking technique hides data into a target signal referred to as the original signal. It, then, generates a slightly distorted signal that is referred to as a stego signal.

Geometric deformation greatly changes the slight distortion conveying hidden data, so a watermarking scheme cannot extract the data, in general. To overcome it, more robust watermarking schemes have been proposed; using relation between two chrominance components [4] or robust features in a transformed domain [5–7]. In contrast, this paper focuses geometric compensation of deformed stego images.

This paper proposes a geometric compensation method for watermarking schemes. The proposed method estimates geometric parameters by using the original image rather than the non-deformed stego image. The phase-only correlation (POC) [8, 9] that estimates parameters in subsamples [10] is employed in the proposed method. The required accuracy for geometric estimation is investigated by computer simulation, and performances are evaluated using real printed-and-scanned images.

## 2. Preliminary

This section describes the phase-only correlation (POC) [8] and the watermarking scheme [7] used for evaluation in this paper.

### 2.1. POC and Its Application to Geometric Estimation

This section defines the POC function [8], and geometric estimation using the POC [8, 9] is described.

Let $f(n_1,n_2)$ and $g(n_1,n_2)$ be two of $N_1 \times N_2$-sized images where $n_1 = 0,1,\ldots,N_1-1$ and $n_2 = 0,1,\ldots,N_2-1$, and $F(k_1,k_2)$ and $G(k_1,k_2)$ are the two dimensional discrete Fourier transformation (2D-DFT) of the two images, respectively. Cross-phase spectrum $R(k_1,k_2)$ between $F(k_1,k_2)$ and $G(k_1,k_2)$ is given by

$$R(k_1,k_2) = \frac{F(k_1,k_2)\overline{G(k_1,k_2)}}{\left|F(k_1,k_2)\overline{G(k_1,k_2)}\right|}, \quad (1)$$

where $k_1 = 0,1,\ldots,N_1-1$, $k_2 = 0,1,\ldots,N_2-1$, and $\overline{G(k_1,k_2)}$ denotes the complex conjugate of $G(k_1,k_2)$. POC function $r(n_1,n_2)$ is given as the 2D inverse DFT of $R(k_1,k_2)$.

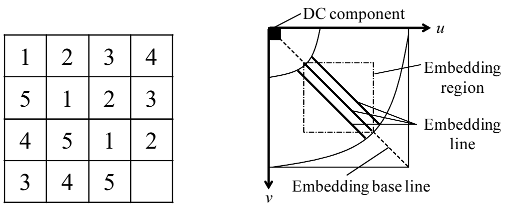
By applying this POC to $f(n_1,n_2)$ and $f(n_1-\delta_1,n_2-\delta_2)$, translational displacements $\delta_1$ and $\delta_2$ are estimated in pixels as the peak position of $r(n_1,n_2)$ [8]. Moreover, for two images $f(n_1,n_2)$ and $g(n_1,n_2)$ where $g(n_1,n_2)$ is rotated $\theta$ and resized $\lambda$ times from $f(n_1,n_2)$, $\theta$ and $\lambda$ are able to be estimated in samples [9], because $\theta$ and $\lambda$ boil down to translational displacements by log-polar mapping (LPM). It is noted this paper uses 16 as the base of the logarithm.

To estimate translational displacements in subsamples, i.e., more accurate, this paper uses a simple extension in which the sampling rate of $r(n_1,n_2)$ is increased by zero-padding in the frequency domain [10]. Reducing the computation amount, it focuses $(2P+1)$ points including the peak of $r(n_1,n_2)$ as its center, and the upsampling is applied to each axis separately. In Sect. 4, the translational displacements and rotation angle are estimated in 0.1 pixels and 0.01 degrees, respectively, with $P = 4$.

### 2.2. Image Watermarking Scheme

This section describes the image watermarking scheme [7] used in performance evaluation in this paper. This scheme embeds $B_n \times B$-bits data to an image where $B$ is the unit of data and $B_n$ is the number of units. $B$-bits data are parallely hidden to a block and are repeatedly hidden to multiple blocks with the following steps.

1. $B_n$ of $L$-length multivalued sequences are generated




(a) Block division and repeat embedding ($K = 4$ and $B_n = 5$).   (b) Parallel embedding in a block.

Figure 1: The image watermarking scheme [7].

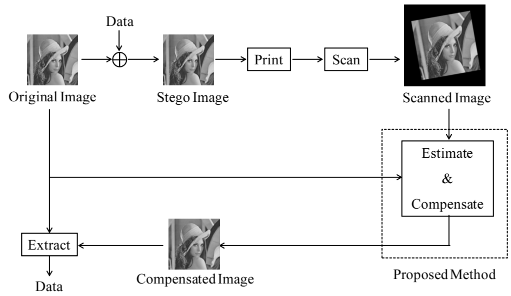



Figure 2: Outline of the system.

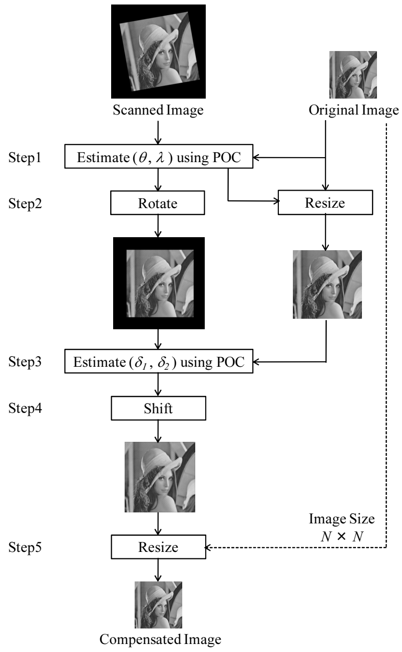



Figure 3: The proposed algorithm.

by parallel spreading of $B$-bits data using $B$ of $L$-length Walsh codes.

2. An original image is divided into $K \times K$ of blocks as shown in Fig. 1 (a), each block is transformed by 2D discrete cosine transformation (2D-DCT). Moreover, blocks are classified to $B_n$ groups shown as Fig. 1 (a).

3. A $L$-length sequence is embedded to a block three times as shown in Fig. 1 (b). One sequence is repeatedly hidden to blocks belonging to the same group as shown in Fig. 1 (a).

4. 2D inverse DCT is applied to each block.

This scheme uses the original image to extract hidden data. $B$-bits data are decided by a majority rule in which $3\lfloor K^2/B_n \rfloor$ of candidates obtained by despreading extracted sequences with $B$ of $L$-length Walsh codes.

For evaluation in Sect. 4, 160 bits data are embedded to an image in which the image is divided into 16 blocks in this paper, namely, $B = 32$, $B_n = 5$, and $K = 4$. Nine candidates, therefore, are available for each 32 bits data in an extraction process. The length of Walsh code is 32, i.e., $L = 32$.

## 3. Proposed Method

This section firstly defines the system in which the proposed method is applied to a watermarking scheme. Then, the proposed estimation and compensation algorithm is described.

### 3.1. Outline of the System

Fig. 2 shows an system example in which the proposed method is applied to a watermarking scheme. The proposed method uses the original image rather than a stego image to compensate the deformed image. It is assumed that a printing-and-scanning process geometrically deforms a stego image as shown in Fig. 2 and that the deformation consists of shifting, rotation, and resizing.

### 3.2. Estimation and Compensation Algorithm

This section proposes the geometric estimation and compensation algorithm. Though this algorithm estimates the rotation angle and the resizing scale, it compensates the size on the image at the end of the algorithm as shown in Fig. 3. Instead, this algorithm resizes the original image rather than deformed image to estimate the translational displacements of the image to be compensated.

The proposed algorithm is as follows in which two images are considered. That is, $N \times N$-sized original image $f(n_1, n_2)$ and $D \times D$-sized image to be compensated $g(n_1, n_2)$ where $N < D$. Image $g(n_1, n_2)$ is assumed to be clipped from a scanned stego image and to contain non-image areas.

1. Estimate angle $\theta$ and resizing scale $\lambda$ of $g(n_1, n_2)$ by using LPM and POC with original image $f(n_1, n_2)$ and the $N \times N$-sized image clipped from the upper left part of $g(n_1, n_2)$.

2. Original image $f(n_1, n_2)$ is resized to $f_\lambda(n_1, n_2)$ by scaling the size $\lambda$ times. Compensate the angle on $g(n_1, n_2)$ to $g_\theta(n_1, n_2)$ by rotating $-\theta$.

3. Estimate translational displacements $(\delta_1, \delta_2)$ by using POC with $f_\lambda(n_1, n_2)$ and $\lambda N \times \lambda N$-sized image clipped from the upper left part of $g_\theta(n_1, n_2)$.

| | |
|---|---|
| Image | airplane, baboon, lena, and sailboat (8 bits grayscale) |
| Image size | $256 \times 256$ pixels |
| Watermark length | 160 bits (equiprobable 0 and 1) |
| Watermark unit | $B = 32$ [bits] |
| Number of blocks | $K \times K = 16$ |
| Number of groups | $B_n = 5$ |
| Walsh code length | $L = 32$ |

Table 1: Conditions for evaluation.

4. Compensate the shift on $g_\theta(n_1, n_2)$ by shifting $(-\delta_1, -\delta_2)$ pixels. A $\lambda N \times \lambda N$-sized image is clipped from the upper left part of the compensated image.

5. Compensate the size of the clipped image to $N \times N$-sized.

### 3.3. Features

The proposed method compensates the deformed image before watermark extraction. Since the proposed method is independent of watermarking schemes, it is expected to not only improve the watermark extraction ability of geometrical deformation vulnerable schemes but also to co-operate with geometrical deformation resilient schemes.

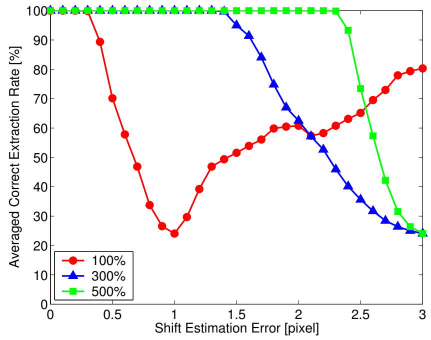
The proposed method compensates the size at the end of its algorithm and resizes the original image rather than the deformed image to compensate translational displacement, whereas the ordinary registration firstly compensate size and angle. The size compensation at the end is expected to reduce the estimation and compensation error of angle and shift, and it is evaluated in Sect. 4.3.

## 4. Experimental Results

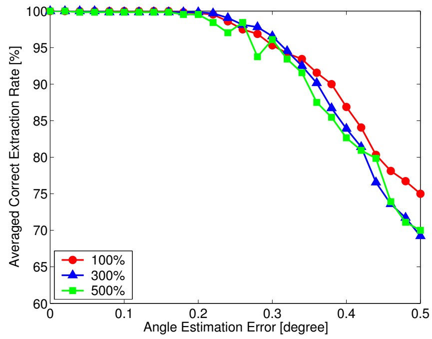
In this section, the proposed method is applied to the image watermarking scheme [7] described in Sect. 2.2. 160-bits random data consisting of equiprobable zeros and ones are hidden to an image in which the image is divided into $4 \times 4$ of blocks and blocks are classified to five groups, i.e., $K = 4$, $B_n = 5$, and $B = 32$. Conditions are summarized in Table 1. The performance measure is the number of correctly extracted watermark bits-to-the number of embedded watermark bits ratio, i.e., the correct extraction rate.

### 4.1. Required Estimation Accuracy

First of all, the required estimation accuracy of geometric parameters for correct extraction of hidden data is investigated. An estimation error lets a compensation error, and it results in a watermark extraction error. From this perspective, computer simulation that do geometrically deform stego images to simulate the compensation error caused by a estimation error is introduced in this investigation. Thus, a stego image is geometrically deformed and, then, is resized to 100 %, 300 %, and 500 %




(a) Shift estimation error.




(b) Angle estimation error.

Figure 4: Correct extraction rate versus estimation error (average for four images).

to simulate oversampling at a scanner.

Fig. 4 (a) shows the correct extraction rate averaged among four images versus shift estimation error in the proposed method. The applied deformation is shifting; from zero pixel to three pixels by 0.1 pixels. Only the size on oversampled images are compensated to investigate the required accuracy in shift estimation. Fig. 4 (a) suggests that shift estimation in samples is enough in the proposed method according to oversampling.

On the other hand, Fig. 4 (b) shows the averaged correct extraction rate versus angle estimation error in the proposed method. The applied deformation is rotation; from zero degree to 0.5 degrees by 0.02 degrees. From Fig. 4 (b), estimation at least 0.1 degrees is required for angle. It generally results in the request of subsample estimation.

### 4.2. Performance for Real Printed-and-Scanned Images

This section evaluates the performance of the proposed method by using real printed-and-scanned images. A stego image is once printed and scanned five times to obtain five deformed images per an image. Additional conditions are summarized in Table 2.

Fig. 5 shows the averaged correct extraction rate versus scanning resolution in the proposed method. In Fig. 5, "nocompensation" eliminates blank spaces and compensates only the size of the image to the regularize image

Table 2: Additional conditions for evaluation with printing-and-scanning.

| | |
|---|---|
| Printer | LP-9100PS3 (EPSON) |
| Printing resolution [ppi] | 75 |
| Printing frequency | 1 |
| Scanner | CanoScanLiDE40 (Canon) |
| Scanning resolution [ppi] | 75, 100, 150, 200, 300, 400, and 600 |
| Scanning frequency | 5 |

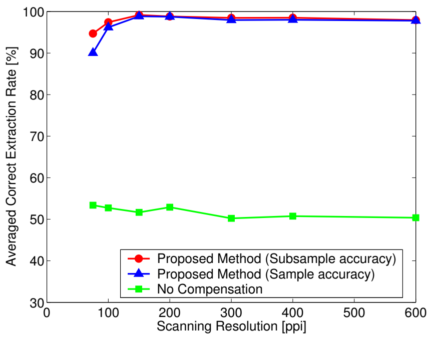



Figure 5: Correct extraction rate versus scanning resolution (average for twenty images).

size. The proposed method improves the extraction rate by geometric compensation. Fig. 5 also shows that the extraction rates are quite similar regardless of estimation accuracy, i.e., shift estimation in samples is enough in the proposed method even for the real printing-and-scanning application.

## 4.3. Performance Difference by Compensation Order

In this section, the proposed method is evaluated in perspective of the compensation order by compared with two algorithms which compensate the deformed image as angle-size-shift or size-angle-shift order. Fig. 6 shows the averaged correct rate versus scanning resolution in all algorithms. From Fig. 6, the proposed method is superior in the extraction rate to compared two algorithms.

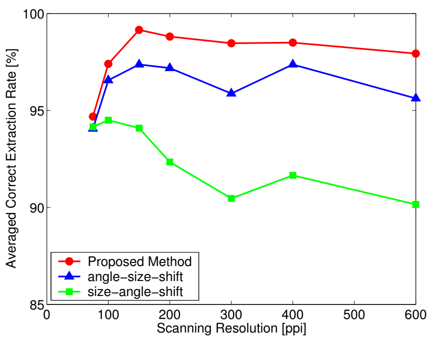



Figure 6: Performance difference by compensation order (average for twenty images).

## 5. Conclusions

This paper has proposed a geometric compensation method to improve the watermark extraction ability. The proposed method compensates the deformed image by geometric estimation using POC. From the result of applying the proposed method to the image watermarking scheme [7], the proposed method can improve the watermark extraction performance with shift estimation in samples according to the scanning resolution.

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