A NEW CLASS OF IMAGE REGISTRATION FOR GUARANTEEING SECURE DATA MANAGEMENT

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ABSTRACT

We propose a method of image registration between scrambled images in order to guarantee the secure data management. This method uses either phase-only correlation or DCT sign phase correlation for the registration. Correlation and registration values between images are directly estimated in the scrambled domain. Information in each image is protected and the relative relation with other images is held by synchronizing scrambling. As a result, the proposed method has no effect on registration accuracy. Translation estimation experiments are performed to show the appropriateness and the effectiveness of the proposed method.

Index Terms— DCT sign phase correlation, phase-only correlation, scrambling, biometrics, image registration

1. INTRODUCTION

Image registration is desired for many fields. Phase-only correlation (POC) or phase correlation is one of methods of image registration [1]-[6]. The study of POC and its applications has advanced. In particular, high accuracy registration by POC with sub-pixel technique is used for biometrics, such as iris [5] and fingerprinting [6]. On the other hand, DCT sign phase correlation (DCT-SPC), which we previously proposed in [7][8], has similar properties of POC. DCT-SPC is derived from the relationship with POC and uses only the signs of DCT coefficients of signals. The utilization of DCT-SPC is expected due to the conciseness of both expression and computational complexity.

Images such as those in biometrics and medical field require extreme care [9]. There are in danger of identity theft and invasion of privacy. In this paper, we propose a new registration method between scrambled images. Exposure of personal information can be prevented by using scrambled images and the secure data management is guaranteed. The proposed method uses either POC or DCT-SPC, and the correlation and registration values between images can be directly estimated in the scrambled domain. Moreover, the proposed method has no effect on registration. The same accuracy of registration as that in non-scrambled images is obtained. Encrypting for secure data management requires decrypting before registration. Conventional methods for registration cannot be applied in the scrambled domain. Estimation of translation between scrambled images is performed to show the appropriateness and the effectiveness of the proposed method.

2. PRELIMINARY

Our concerns are expressed to clarify our motivations. DCT sign phase correlation (DCT-SPC) and phase-only correlation (POC) are explained with one-dimensional expression for brevity.

2.1. Concerns

Generally, the management of data demands a lot of attention. Measure for theft and refusal of cross-references[1] are required. The data for reference using DCT-SPC or POC should be stored in either raw data or feature data such as DFT coefficients, their phase information, and DCT signs. If the raw data were to be stolen, the information is leaked out. If the feature data were to be stolen, the information is exposed by the inverse transform of either DCT signs or DFT phase information as shown in Fig. 1. In addition, both raw data and feature data are not considered about cross-references.

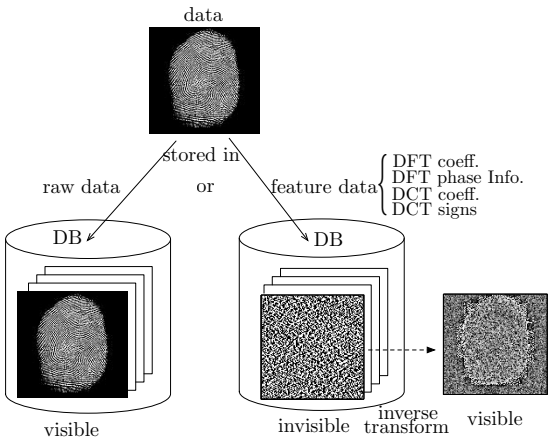
Our motivations are to propose how to scramble the data for image registration using DCT-SPC or POC, and to show that the proposed method has no effect on registration accuracy.

2.2. DCT sign phase correlation (DCT-SPC) [7][8]

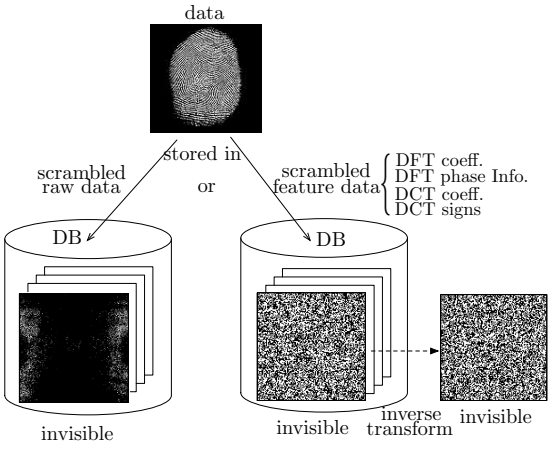
Let the N-point signal be $g_1(n)$ and $g_2(n)$, $(n = 0, 1, \cdots, N\text{–}1)$. Let also their signs of DCT coefficients, referred to as DCT signs, be $\sigma_{G_1}(k)$ and $\sigma_{G_2}(k)$, $(k = 0, 1, \cdots, N\text{–}1)$, respectively. The DCT sign product is defined as

$$R_\sigma(k) = \sigma_{G_1}(k) \cdot \sigma_{G_2}(k). \quad (1)$$

[1] The data registered in a system is diverted in another system without the permit of a registrant.



(a) risk of compromise.



(b) secure data management for compromise.

Fig. 1. (a) risk of compromise: If raw data in a database were to be stolen, the information is leaked out. If feature data in a database were to be stolen, the information is exposed by the inverse transform of either DCT signs or DFT phase information. (b) secure data management for compromise: Data is stored in either scrambled raw data or scrambled feature data in order to guarantee secure data management.

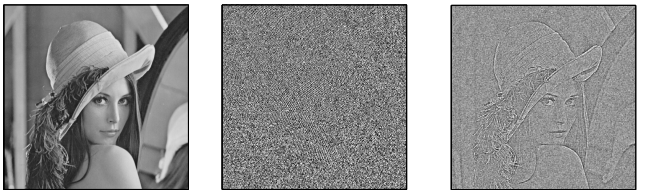
DCT-SPC is defined using DCT sign product, $R_\sigma(k)$ as

$$r_\sigma(n) = \frac{1}{N}\sum_{k=0}^{N-1} K_k R_\sigma(k)\cos\left(\frac{\pi nk}{N}\right) \tag{2}$$

where,

$$K_k = \begin{cases} 1, & k \neq 0 \\ 1/2, & k = 0 \end{cases}. \tag{3}$$

Figures 2 (a) and (b) show an original image and its DCT signs, where white points denote positive signs (+1) and black points denote negative signs (-1), respectively. Although in DCT signs, one cannot recognize the information about (a), once the inverse DCT (IDCT) is applied to the DCT signs, the information is exposed as shown in (c). The image generated from DCT signs by the IDCT is referred to as DCT sign-only image.



(a) original image (b) DCT signs (c) DCT sign-only image (IDCT of (b))

Fig. 2. Information exposed by the inverse transform.

2.3. Phase-only correlation (POC) [2]–[6]

Let the DFT coefficients of $g_1(n)$ and $g_2(n)$ be $G_1(k)$ and $G_2(k)$, $(k = 0, 1, \cdots, N-1)$, respectively. The phase factor $\phi_{G_i}(k)$, $(i = 1, 2)$ is defined by

$$G_i(k) = |G_i(k)|\phi_{G_i}(k) \tag{4}$$

where $|G_i(k)|$ denotes the magnitude of $G_i(k)$. If $|G_i(k)|$ is zero, then $\phi_{G_i}(k)$ is replaced by zero [2]. The normalized cross spectrum is given as

$$R_\phi(k) = \phi_{G_1}(k)\cdot\phi^*_{G_2}(k) \tag{5}$$

where $\phi^*_{G_2}(k)$ is the complex conjugate of $\phi_{G_2}(k)$. POC is defined as

$$r_\phi(n) = \frac{1}{N}\sum_{k=0}^{N-1} R_\phi(k) W_N^{-nk} \tag{6}$$

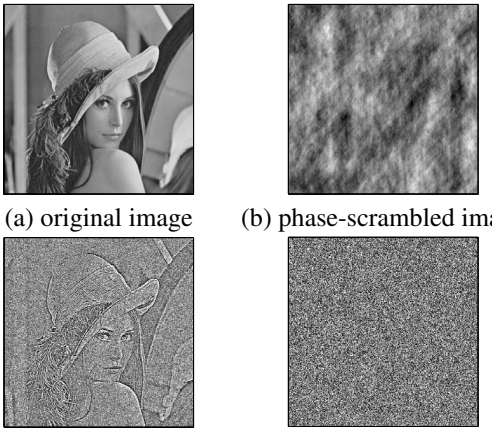
where W_N^{-nk} denotes $e^{j2\pi nk/N}$. When the inverse DFT (IDFT) is applied to DFT phase factors, the original information is revealed immediately. The image generated from DFT phase factor by the IDFT is referred to as phase-only image.

3. REGISTRATION BETWEEN SCRAMBLED IMAGES

In this section, it is explained how to scramble images and is shown that the proposed method has no effect on registration. One-dimensional expression is used for brevity, although multi-dimensional expression should be used.

3.1. Scrambling images

Let us consider scrambling the DCT coefficients $G_{C_i}(k)$, $(i = 1, 2)$, $(k = 0, 1, \cdots, N-1)$. The steps are very simple. First,



(a) original image (b) phase-scrambled image

(c) phase-only image (d) scrambled phase-only image

Fig. 3. Effectiveness of scrambling in DFT coefficients.

signs, $s_{\alpha_i}(k) \in \{1, -1\}$, $(k = 0, 1, \cdots, N-1)$ are generated in random order by using a random number generator with a key, α_i. Then, the scrambled DCT coefficient, $\widetilde{G_{C_i}}(k)$, is obtained by multiplying $s_{\alpha_i}(k)$ by $G_{C_i}(k)$, i.e.,

$$\widetilde{G_{C_i}}(k) = s_{\alpha_i}(k) \cdot G_{C_i}(k) \tag{7}$$

The relationship between scrambled DCT sings, $\widetilde{\sigma_{G_i}}(k)$, and non-scrambled ones, $\sigma_{G_i}(k)$, is given as

$$\widetilde{\sigma_{G_i}}(k) = s_{\alpha_i}(k) \cdot \sigma_{G_i}(k). \tag{8}$$

Similarly, let us next consider scrambling DFT coefficients $G_i(k)$, $(i = 1, 2)$, $(k = 0, 1, \cdots, N-1)$. The scrambled DFT coefficient, $\widetilde{G}_i(k) = |\widetilde{G}_i(k)|\widetilde{\phi_{G_i}}(k)$, is obtained by multiplying $s_{\alpha_i}(k)$ by $G_i(k)$. i.e.,

$$\widetilde{G}_i(k) = s_{\alpha_i}(k) \cdot G_i(k). \tag{9}$$

From Eq. (9), the phase factor, $\widetilde{\phi_{G_i}}(k)$, is given as

$$\widetilde{\phi_{G_i}}(k) = e^{-j(s_{\alpha_i}(k)-1)\pi/2}\phi_{G_i}(k). \tag{10}$$

Figures 3. (a), (b), (c), and (d) show an original image, a phase-scrambled image, a phase-only image, and a scrambled phase-only image, respectively. The phase-scrambled image is the IDFT of scrambled DFT coefficients, and the scrambled phase-only image is the IDFT of scrambled phase factors. Compared with (c), both (b) and (d) protect the information about (a). Changing signs makes it possible to generate scrambled images for secure data management.

3.2. Registration under scrambling

According to Eq. (1), the DCT sign product $\widetilde{R_\sigma}(k)$ between $\widetilde{\sigma_{G_1}}(k)$ and $\widetilde{\sigma_{G_2}}(k)$ are given as

$$\begin{aligned}\widetilde{R_\sigma}(k) &= \widetilde{\sigma_{G_1}}(k) \cdot \widetilde{\sigma_{G_2}}(k) \\ &= s_{\alpha_1}(k) \cdot \sigma_{G_1}(k) \cdot s_{\alpha_2}(k) \cdot \sigma_{G_2}(k)\end{aligned} \tag{11}$$

where, if the same key is used, i.e., $s_{\alpha_1} = s_{\alpha_2}$, then

$$s_{\alpha_1}(k) \cdot s_{\alpha_2}(k) = 1 \tag{12}$$

and

$$\widetilde{R_\sigma}(k) = R_\sigma(k). \tag{13}$$

If the keys are different, i.e., $\alpha_1 \neq \alpha_2$, then $\widetilde{R_\sigma}(k) \neq R_\sigma(k)$. In the case of scrambled DFT coefficients, if the common key is used, then the normalized cross spectrum is invariant. The proposed scrambling has no effect on registration accuracy.

3.3. Registration steps for guaranteeing secure data management

Registration between two images using DCT-SPC or POC is accomplished according to the following steps:

Step 1 The DCT / DFT is applied to images.

Step 2 The DCT / DFT coefficients are scrambled according to Eq. (7) / Eq. (9)

Step 3 The DCT signs / DFT phase factors are extracted.

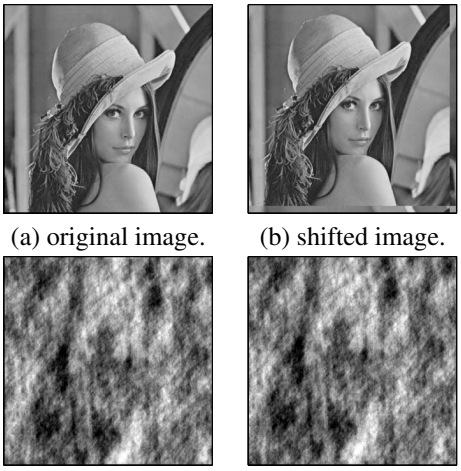
Step 4 The DCT signs product / normalized cross spectrum is calculated according to Eq. (1) / Eq. (5).

Step 5 The inverse transform is applied to the result of Step 4 according to Eq. (2) / Eq. (6).

These steps are ordinary steps for DCT-SPC / POC except Step 2. Adding Step 2 ensures secure data management for registration. In addition, the accuracy of registration is the same as in non-scrambling case. The proposed scrambling has no effect on registration.

4. SIMULATION

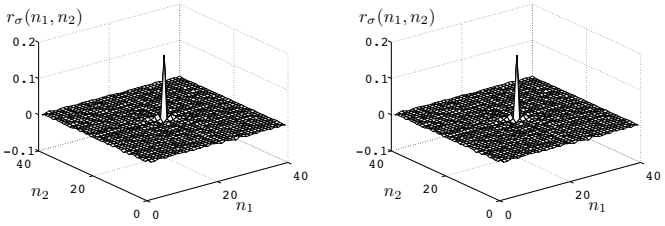
We estimated the translational displacement between images in Fig. 4, where (b) is created from (a) shifted by 20 pixels in both the horizontal and the vertical directions, respectively, and (c) and (d) are their phase scrambled images generated according to Eq. (7). Figure 5 (a) shows the DCT-SPC surface between non-scrambled images, (a) and (b) in Fig. 4. Figure 5 (b) shows the DCT-SPC surface between scrambled images, (c) and (d) in Fig. 4. From Fig. 5, we can see that an peak appeared at the location which corresponds to the translation. We confirmed that the DCT-SPC surface between non-scrambled images and that between scrambled image were identical. The scrambling has no effect on registration accuracy. The results using POC is shown in Fig. 6. We also confirmed that the result of non-scrambled images and that of scrambled images were identical.



(a) original image. (b) shifted image.

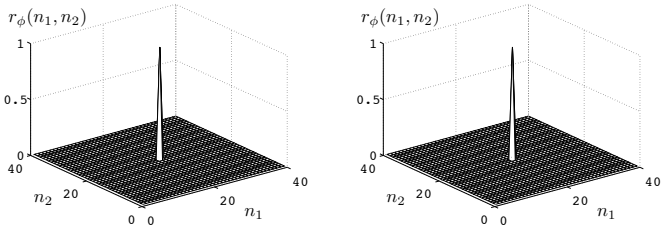
(c) phase-scrambled original image (d) phase-scrambled shifted image

Fig. 4. Test images. (256×256)



(a) non-scrambled images. (b) scrambled images.

Fig. 5. Estimation of translation using DCT-SPC.



(a) non-scrambled images. (b) scrambled images.

Fig. 6. Estimation of translation using POC.

5. CONCLUSION

We have proposed a registration method between scrambled images. The method can be utilized for either POC or DCT-SPC. We have explained how to generate scrambled images and shown that the proposed method protects the information in each image and can directly estimate the registration values in the scrambled domain. The proposed method has no effect on registration accuracy. Translation estimation has been demonstrated to show the appropriateness and the effectiveness of the proposed method.

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