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Discrete Polar Complex Exponential Transform for Image Rotation Duplication Detection

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Abstract. This paper through Comparative analysis of This Discrete Polar Complex Exponential Transform approach is improved from traditional Polar Complex Exponential Transform (PCET) and this transform also encompasses the features of orthogonality and rotation invariance. We introduce a new 9×9 circle instead of a unit circle in DPCET to calculate features of image more precision. And various experiments were performed to prove that effectiveness of our approach in detecting duplicated forgeries, with translation, rotation, noise addition. And the experiment results also show that our approach is more robust to geometric distortions of the duplicated regions than other compared approaches.

Keywords: Digital forgery images, Complex Exponential Transform, 9×9 circle, Discrete Polar Harmonic Transforms.

1 Introduction

Over the past decade, information forensics and security become popular and attract much more people's attention. Image forensics is a key problem of information forensics and security field in today's society. Hence, image forgery detection is an important area of research in the field of social livelihood, scientific discovery, court evidence, financial document, news reports et al. With the development of the powerful photo processing software, some malicious users can perform forgery images to achieve their desired purposes. A common manipulation in tampering with digital images is known as region duplication, where a continuous portion of pixels are copied and pasted to a different location in the same image in order to conceal an important object in the scene [1]. Forgery meeting between President Clinton and Saddam Hussein is shown in Fig.1. We focus on image forgery detection and aim at establishing correspondence between the same or similar duplicated parts which appear in one image or other different images.

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INTERNET

Spies turn to high-tech info ops

PCs, Internet used for manipulating images, public opinion

ALTERED IMAGE

1 2 3

Altered Egos

The top photo, of a fictitious meeting between President Clirton and Saddam Hussein, was generated by digitally altering and combining elements from three photos, shown below the altered image. Intelligence agencies plan to use similar techniques to create images and then disseminate them via the Internet in their efforts to influence events in foreign countries, such as Iraq.

BY DANIEL VERTON

Federal intelligence agencies are studying ways to use computers and the Internet, rather than just leaflets and radio broadcasts, to shape and disseminate information designed to sway public opinion in the world's hot spots.

As part of its so-called "perception management" program, the intelligence community has for decades created misinformation to trigger political change without direct political or military involvement in countries where the United States has vested interests, such as Iraq and North Korea.

Acting on congressional recommendations to bolster research and development in information technology, intelligence agencies are turning to PCs to develop more sophisticated means of manipulating and delivering digital photos, video clips and recorded sound to portray fictitious events in hopes of provoking desirable outcomes.

Fig. 1. Forgery duplicated image of meeting between President Clinton and Saddam Hussein

Some general approaches are proposed to detect and locate duplicated forgery images. Fridrich [2] proposed approach base on Discrete Cosine Transform (DCT) coefficients which is one of the most widely-used techniques for duplicated forgery detection. But this approach has a low efficiency. In order to increase efficiency, Popescu et al. [3] proposed an approach based on the principal component analysis (PCA). PCA approach can reduce dimensionality of the matrix and get the aim to reduce computational complexity and cost. Cao et al. [4] and Huang et al. [5] also proposed an improved DCT mean coefficient approach and aimed to reduce the dimension of the feature vectors used by the Fridrich's algorithm. Zhang et al. [6] proposed an approach based on the pixel-matching for detecting and locating Copy-Move regions within an image. Chakraborty et al. [7] proposed an approach to joint histogram and mutual information for detecting illumination change in duplicated region. Kashyap et al. [8] proposed an approach based on wavelet decomposition.

The above detection approaches can detect forgeries in images well in the absence of post-processing operations. But this is not always the case. These general detection approaches typically do not provide valid evidence of region duplication or the location of the duplicated regions when the duplicated regions are suffered from geometric distortion. Considering image geometric distortion with translation, rotation and mirror is a key factor of image quality. Due to geometric invariant moments are highly concentrated on geometric transformation of image features, therefore, in the field of image duplication detection, geometric transformation (rotation, translation and scaling) invariance analysis is an important research content. In recently years, research on geometric distortion of forgery duplication image has been obtained fruitful achievements in the study of geometric moment invariants. Various kinds of moment invariants are proposed in the past decades. HU [9] moments are first proposed and Hu moments are widely-used techniques for duplicated forgery detection. Teh [10] ever proposed and evaluated a number of moments and addresses some fundamental questions. Latter various types of moment invariants are appeared to detect duplicated region of images. Popular and representative moment invariants approached are divided into several groups.

2 The Review of the 2-D Polar Harmonic Transforms

In this section, we have grouped three types' transforms which is Polar Complex Exponential Transform (PCET), Polar Cosine Transform (PCT), and Polar Sine Transform (PST) under the name Polar Harmonic Transforms as the kernels of these transforms. These three type transforms are harmonic basic waves of PHTs.

2.1 Definition of Polar Complex Exponential Transform (PCET)

The general 2-D moment definition using a moment weighting kernel, namely basis function $H_{nl}(x, y)$, and an image intensity function $f(x, y)$ is given as

$$M_{nl} = \frac{1}{\pi}\int_0^{2\pi}\int_0^1 H_{nl}^*(x, y)\, f(x, y)\, dxdy \tag{1}$$

Given a 2D image function $f(r,\theta)$, it can be transformed $f(x, y)$ to it from Cartesian coordinate to Polar coordinate. The transforms in this set of function $f(r,\theta)$ is defined as [21, 22]

$$M_{nl} = \frac{1}{\pi}\int_0^{2\pi}\int_0^1 H_{nl}^*(r,\theta)\, f(r,\theta)\, rdrd\theta \tag{2}$$

Where M_{nl} is Polar Complex Exponential Transform (PCET) of $f(r,\theta)$, with order n and repetition l. where $|n|,\ l = 0,1 \ldots, \infty$. $H_{nl}(r,\theta)$ is a basis function of PCET, $H_{nl}^*(r,\theta)$ indicates the complex conjugate of the $H_{nl}(r,\theta)$. For PCET, $H_{nl}^*(r,\theta)$ is consisted of radial and circular components and can be defined as

$$H_{nl}^*(r,\theta) = R_n^*(r)e^{-il\theta} = e^{-i2\pi nr^2}e^{-il\theta} \tag{3}$$

Where $R_n(r)$ is the radial kernel, i is a imaginary and $i = \sqrt{-1}$, r indicates radius defined on unit circle and θ indicates rotation degree which are defined as

$$r = \sqrt{x^2 + y^2},$$
$$\theta = \tan^{-1}\left(\frac{y}{x}\right) \tag{4}$$

$R_n(r)$ is satisfy orthogonal condition, and defined as [21]

$$\int_0^1 R_n(r)R_{n'}^*(r)rdr = \frac{1}{2}\delta_{nn'}$$

(5)

$$\int_0^{2\pi}\int_0^1 H_{nl}(r,\theta)H_{n'l'}^*(r,\theta)rdrd\theta = \pi\delta_{nn'}\delta_{ll'}$$

(6)

2.2 Definition of Polar Cosine Transform (PCT) and Polar Sine Transform (PST)

Similar to the form of PCET, Polar Cosine Transform (PCT) is defined as [21]

$$M_{nl}^{C} = \Omega_n \int_0^{2\pi} \int_0^1 [H_{nl}^{C}(r,\theta)]^* f(r,\theta) r dr d\theta$$

(7)

Polar Sine Transform (PST) is defined as

$$M_{nl}^{C} = \Omega_n \int_0^{2\pi} \int_0^1 [H_{nl}^{S}(r,\theta)]^* f(r,\theta) r dr d\theta$$

(8)

Where the basis function of PST and PCT are defined as

$$\begin{cases} H_{nl}^{C} = \cos(n\pi r^2) e^{il\theta} \\ H_{nl}^{S} = \sin(n\pi r^2) e^{il\theta} \end{cases}$$

(9)

Where $\Omega_n = \begin{cases} \frac{1}{\pi}, & if \quad n = 0 \\ \frac{2}{\pi}, & if \quad n \neq 0 \end{cases}$, $|n|, \ l = 0,1 ..., \infty$

3 Conclusion

With the rapid development of computer technology, normal users can perform duplicated region operation easier for creating a realistic composite image. As such it is also significant to detect these duplicated operations for verifying and authenticating the originality of the digital images. In this paper, we have presented the overview of the advance techniques in image forensics and security applications. We have focused on the localization and detection of image duplicated forgery, for which we advocate Discrete Polar Harmonic Transforms as geometry feature representation of small duplicated overlapping image blocks which size is at least 32×32 pixels. For the geometric features, we proposed to construct rotation moment invariant and extract its rotation invariance. The detail formula derivation is discussed and analyzed in section 3. And the latter experiments can all be viewed in support of the above decision of formula derivation. All experimental results strongly suggest that localization and detection performance greatly depends on image geometric features, such as translation, rotation. The experiments in section 4.1 shows that the proposed approach can detect duplicated forgery images successfully, and furthermore, even if the duplicated forged image is subjected to rotation transform and additive Gaussian noise. When the size of duplicated region is larger than 32×32, we will achieve higher level of accuracy. The experiments in section 4.2, we introduce the image False Detecting Rate (FDR) to authenticate misjudgment of our proposed approach in detecting nature or no being tampered image. In section 4.3, we compared the robustness of our approach with the previously proposed approaches which also research on duplicated rotation region in paper [14], [20]. Our proposed approach based on rotation moment invariants show more excellent. But the precision of our proposed approach in detecting of $(2n+1)\pi/4$ is not relatively high. This is due when the duplicated region or sub-image which is rotated to $(2n+1)\pi/4$ closely will led to change the relatively position of neighboring pixels which are realize to fill a certain pixel values greatly. In addition, we slide one pixel each time to detect the whole image which will lead to low efficiency. So in the next step, we will accelerate correlated work and improved detection approach to enhance robustness, increase precision and improve efficiency, make the approach for the duplicated rotation region of image detection more efficient.

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