Robust Evidence Detection of Copy-Rotate-Move Forgery in Image Based on Singular Value Decomposition

Liu Yong[1,2], Huang Meishan[1,2], and Lin Bogang[1,2]

[1] College of Mathematics and Computer Science of Fuzhou University, Fuzhou, 350108, China
[2] Key Lab of Information Security of Network Systems, Fuzhou, 350108, China
{553761346,562444526}@qq.com, linbg95@163.com

Abstract. Region Copy-Move forgery, in which a part of the image is copied and then pasted to another part of the same image. Some important goals and sensitive objects can be hidden imperceptibly; this forgery is at the rather important position in a variety of forensic technology research. But the literatures published merely are confined without geometric distortion. And some algorithms focus on the special forgery's model. In order to improve the accuracy of the current algorithms, a new detection is proposed by constructing the circles rather than the traditional ways which were based on the square. The seven characterizes are constructed according to singular value decomposition. Using main rotation angle based on the radial moment and the proportion of constraint remove the error mark. Finally the dictionary-ordering method is applied to save the time-consuming. The experiment shows that this newly characteristic can locate the area where was tampered.

Keywords: Blind image forensics, Rotation invariant, Singular value decomposition, Radial moment, Copy-Rotate-Move Forgery.

1 Introduction

With the wide application of powerful digital image processing software, such as Photoshop .It has been becoming easier to create forgeries from one or more images. The effective algorithm must be researched and applied to judge whether the image has been modified. Meanwhile the current researches focus on the passive authentication, which also called blind forensic, is the method to make authentication without any help of the auxiliary information.

In recent years, some scholars have started to develop passive techniques for detecting various methods of image forgeries. Fridrich proposed several statistical methods for detecting forgeries based on pattern noise of cameras' sensor[1,2] Popecu and Farid presented method based on color filter interpolation and re-sampling[3,4]. Luo gave a proper model for region-duplication forgery, where the seven features are calculated for four basic constraints of region-duplication forgery, including two connectivity regions and two un-intersection regions [5].

The methods mentioned above have a limitation, when the copy region is rotated, the manner choosing square image blocks will fail because of dislocation. We propose a

T.W. Chim and T.H. Yuen (Eds.): ICICS 2012, LNCS 7618, pp. 357–364, 2012.

new manner matching the blocks based on the circle. Singular value decomposition is used to extract the image blocks' characteristic.

The rest of the paper is organized as follows. In section 2, the new forgery model is introduced. The mechanism of feature extraction and the detection method are presented in detail in Section 3. In section 4, some experimental results and the corresponding analysis is presented. Finally, we concluded in Section 5.

2 Proposed Model

It is known that we can hardly find the two same parts in one natural image. However when the regions-rotate-duplication happened, two or more similar parts must be existed, although it hardly is seen by naked eyes.

Before the model is given, two hypotheses are introduced in advance.

1. The copy region must be the no-holes and connected.
2. The copy region and paste region have no public set, and their Euclidean distance also is greater than the certain value.
3. The model of Copy-rotate-duplication is given as follows

$$F(x,y)=\begin{cases} I(x,y) & (x,y)\notin R_c \\ T(I(x-\Delta x,y-\Delta y))*h(x,y)+n(x,y) & (x-\Delta x,y-\Delta y)\notin R_o \end{cases} \tag{1}$$

Here, T denotes the transform matrix of copy regions, $(\Delta x,\Delta y)$ denotes the translation value, h denotes the fuzzy operation and fuzzy core, and n is the noise and other operations. Our aim is to search the R_c and R_o in one image.

3 Proposed Detection Scheme

3.1 Preprocessing

Gaussian pyramid is a common decomposition way often used in image processing, the technique involves creating a series of mage which are weighted down using a Gaussian average and scaled down, when the technique is used multiple times. it creates a stack of successively smaller images, with each pixel containing a local average that corresponds to a pixel neighborhood on a lower level of the pyramid. Fig 2 gives the illustration about Gaussian pyramid decomposition.

Let the original image be I_0, which is taken as the zero level, the I_i level image of Gaussian pyramid can be obtained by making the I_{i-1} level image convoluted by a window function $w(m,n)$ with low-pass characteristics, and doing the down sampling after the convolution. The process can be described as:

$$I_i = \sum_{i=-w}^{i=w}\sum_{j=-w}^{j=w} w(m,n) I_{i-1}(2*w+m, 2*w+n) \tag{2}$$

Here, the window function w is also called the weight function or generation kernel, whose size is usually chosen as $5*5$ .The Gaussian pyramid decomposition can reduce the complexity of the detection algorithm.

3.2 Definition and Characteristics of SVD

Definition: $\mathrm{A}_{\mathrm{m*n}}$ is a matrix (assume $m \geq n$), the matrix U_{m*n} , V_{m*n} and diagonal matrix $\Im_{m*n}$ can satisfies the following equation. $A = U\Im V^T$, where $\Im = diag(\lambda_1, \lambda_2, ..., \lambda_k, 0,0,0).(\lambda_1 \geq \lambda_2 \geq ... \geq \lambda_k)$, $U = (U_1, U_2, ..., U_m)$, $V = (V_1, V_2, ..., V_m)$ and $\lambda_i^2 (i = 1,2,...k)$ is the Eigen values of the matrix AA^T and $A^T A$, λ_i is called the singular of A . For any real matrix A , $\lambda_1 \geq \lambda_2 \geq ...... \geq \lambda_k$ .In singular value decomposition, diagonal matrix $\Im_{m*n}$ is unique.

Proposition 1: Assume that there are two real matrixes $\mathrm{A}_{m*n}, B_{m*n} \in R^{m*n}$, their singular values are $\lambda_i' \geq \lambda_2' \geq ...... \geq \lambda_n'$, $\lambda_1'' \geq \lambda_2'' \geq ...... \geq \lambda_n''$ respectively, for any unitarily invariant norm on R^{m*n} satisfies

$$\left\| diag(\lambda_1'' - \lambda_1', \lambda_2'' - \lambda_2', ..., \lambda_n'' - \lambda_n') \right\| \leq \left\| B - A \right\| \tag{3}$$

Because singular value has a good stability, it is not sensitive to noise and lighting condition for grayscale change.

Proposition 2: For element orthogonal matrix, such as $\mathrm{Q} = I - 2VV^T$, where I denotes the unit matrix, V is a real vector, whose length is 1 and dimensions is n . For rotate operation, the rotation transform matrix can decompose multiplication with two orthogonal matrixes. For the real matrix A , rotating it means that $\mathrm{A} * \mathrm{P}$, P is an orthogonal matrix.

$$(PA)(PA)^T = p(AA^T)P^T \tag{4}$$

Where $P^T = P^{-1}$, because AA^T and $P(AA^T)P^T$ have a same Eigen values. Therefore we can say the singular value is robust for rotation.

Proposition 3: Translation is equivalent to replacing two rows or columns, exchanging the ith, jth of matrix means multiplying the following matrix on the left of A,

$$I_{i,j} = I - (e_i - e_j)(e_i - e_j)^T \tag{5}$$

Where e_i and e_j denote the ith and jth rows of matrix respectively. After translation, A became $I_{i,j}A$, meanwhile $I^T{}_{i,j} = I_{i,j} = I^T{}_{j,i}$. The characteristic equation of matrix ($(I_{i,j})A(I_{i,j}A)^T$) is as following:

$$(\left|\mathrm{I}_{i,j}A)(I_{i,j}A)^T - \lambda I\right| = 0 \tag{6}$$

$\left|I_{i,j}AA^T I^T{}_{i,j} - \lambda I\right| = \left|I_{i,j}\right| \times \left|AA^T - \lambda I_{i,j} I^T{}_{i,j}\right| \times \left|I_{i,j}\right| = \left|AA^T - \lambda I\right|$。 We can conclude that singular value is also robust for translation. Singular value decomposition possesses some variances on algebra and geometry. It not only provides a theoretical basis of image as an algebraic feature, but also for the copy-rotate-duplication detection.

3.3 Rotation Estimation Based on the Radial Moment

In copy-duplication detection, copy region and paste region have the same translation direction, many papers proposed several methods based on the main translation vector. While In copy-rotate-duplication detection, those methods almost failed. In this paper, according to the fact that the blocks in paste region have the same rotate parameters relative to the copy region, calculating the rotate parameter using the radial moment. Definition of radial moment:

$$\psi(k,p,q,l) = \int_{r=0}^{\infty} \int_{\theta=0}^{2\pi} r^k \cos^p \theta \sin^q \theta e^{il\theta} g(r,\theta) dr d\theta \tag{7}$$

where (r,θ) denotes polar coordinates of image pixels, $g(r,\theta)$ presents the distribution of brightness in image. k,p,q,l must be integers, and p, q are non-negative.

Assume α is the angle of rotation of image and s is the scale factor, the polar coordinates will be:

$$r' = s * r \,, \theta' = \theta + \alpha \tag{8}$$

The raw image and rotated image meet:

$$\psi'_{k,d} = s^{k+l} e^{ikd} \psi_{k,d} \tag{9}$$

While in computing, $s = 1$, We can easily get the information about rotation parameter.

3.4 Forgery Detection

Firstly, the doubtful image is decomposed by Gaussian pyramid, and the produced sub-image is in low frequency is chosen to overcome the possible distortion. Then the sub-image is divided into many circle blocks overlapping each other, the features of singular values are extracted from the circle blocks, used as the matching features. The dictionary sort is applied to reduce complexity of researching space. We use a main rotation angle to remove the mistaking blocks. Finally the morphology is used to fill the hole-regions. Area radio is helpful to improve the accurate of algorithm. The detailed steps of algorithm are as follows:

1. Note regarding color images: In both Extra and Robust Match, if the analyzed image is a color image, before proceeding with further analysis, it is first converted to a gray image using the standard formula $I = 0.299R + 0.587G + 0.114B$, where I_{m*n} denotes the image, its size is $m*n$.

2. The image I'_{a*b} is decomposed by Gaussian pyramid, $a = \lfloor m/2^i \rfloor, b = \lfloor n/2^i \rfloor, i = 1,2,.., \min(\lfloor \log 2^m \rfloor, \lfloor \log 2^n \rfloor)$.

Suppose the size of the slider window is $r*r$. In actual detection, the size of forgery area is usually bigger than windows' size, considering the time-consuming and accuracy of algorithm. The step of slider windows is $r/2$, the numbers of blocks are $N = (2a/r-1)*(2b/r-1)$.

3.The features are extracted by singular value decomposition of each image block, and the singular value vector is construct, which is denoted by $X = (x_1, x_2, ...x_r)$.

4. The all eigenvectors are stored in the matrix A, and the rows of A are lexicographically sorted as before. Then we compute the similarity of the two neighboring Eigenvectors. It can be measured by the Euclidean distance $d_{i,j}$.

$$d_{i,j} = \sqrt{\frac{\sum_{k=0}^{n} (x_{ik} - x_{jk})^2}{n}} \tag{10}$$

x_{ik}, x_{jk} denotes the different eigenvectors respectively, and n is the dimension of the eigenvector.

5. According to the experience threshold. d_{opt} Thus, the algorithm also looks at the mutual positions of each block pair and outputs a specific block pair only if there are many other matching pairs in the same mutual position (the have the same rotate angle). Towards this goal ,if consecutive rows are found, the algorithm stores the positions of the matching blocks in a separate list(for example, the coordinates of the upper left pixel of a block can be taken as its position)and increments a rotation angle counter C ,the rotation angle θ between the two matching blocks is calculated by the radial moment. Then round θ to the integer and compute $sum(\theta) = sum(\theta) + 1$. The main rotate angle must be the maximum value of sum in all angles, calibrate the neighboring image blocks which meet the above conditions. Finally the holes doubtful region is filled by morphology, such as dilate and erosion.

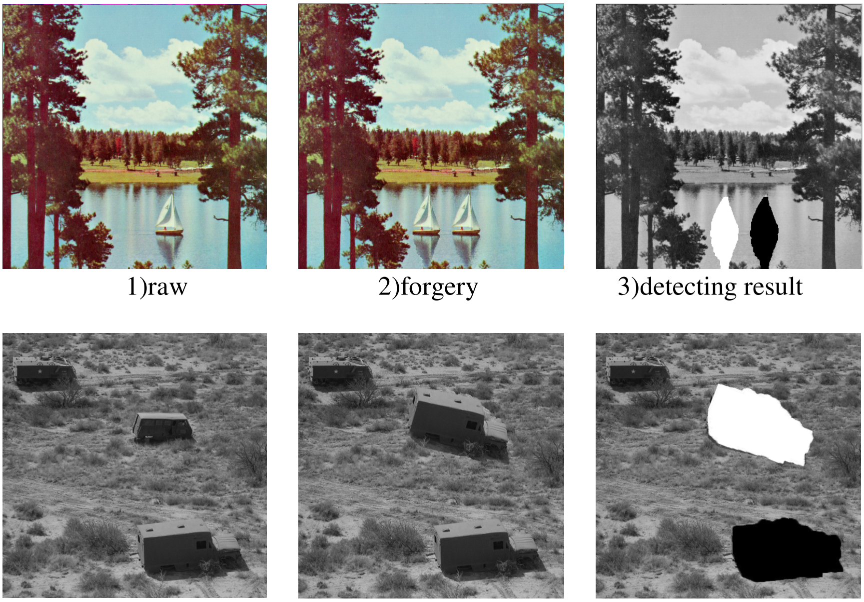
6. Compute the area of each the connected region, all the regions is sorted by the size of the regions, the result is denoted by S, where $S = (s_1, s_2, ..., s_N)$, N is a number of regions. We calculate the radio of two consecutive regions.

$$\rho_i = \frac{s_i}{s_{i+1}} \tag{11}$$

The copy-rotate-duplication must be hold below condition: $\exists \rho_k, \forall \rho_l, \rho_k < \rho_l, k \neq l, k, l \in (1, N)$, where k is the index of the copy-rotate-duplication region.

4 Experimental Results

4.1 Effectiveness of Algorithm



1)raw 2)forgery 3)detecting result

4)raw 5)forgery 6)detecting result

Fig. 1. Detection result of Copy Move Forgery regions

In the first part of this section, we apply the method to several examples. An experimental version of the proposed method was implemented in Matlab. Here test images have resolution of 512*512. Parameters of the method were set $r = 8$, $d = 1.25$, $N = 7$. In all experiments, the mean of additive Gaussian noise is zero and intensity levels are in the range $0 - 255$. The raw images are shown in Fig 1 1(row) and 4(row) respectively. The respective forgery images are shown in Fig 1 2(forgery) and 5(forgery). Outcomes of the method are shown in Fig 1 3(detecting result) and 6(detecting result).

4.2 Comparison with Relative Literatures

Compared to [1, 3, 6], the proposed method uses a more information about rotation. Proposed approaches literatures are not robust for the rotation operation. Meanwhile, the larger number of image blocks need more time and memory.

Table 1 show that our method proposed a new detection algorithm based on the Gaussian pyramid decomposition and singular value decomposition. The radial moment also plays a very important role in the proposed method, the main rotation angle

Table 1. Comparison result of reference' approaches with proposed approaches

algorithm	Eigenvectors	Number blocks	dimension	rotation
Fridrich	DCT&quantization	255025	64	no
Farid	PCA	255025	32	no
Wu q	DWT&SVD	62001	8	no
Our method	GPD&SVD	3969	7	yes

firstly used to remove the mismatch blocks. Thanks to the important characteristic of singular value decomposition, it provides a theoretical basis of image as algebraic features. Meanwhile its uniqueness and stability also provide a theoretical basis for the copy-rotate-duplication detection. Experiment shows that the proposed method is robust for additive Gaussian noise and retouching, locating the forgery regions accurately.

5 Conclusion

Our proposed does not work well in the copy-scale-duplication cases. All the literatures based on the overlapping blocks hardly detect this forgery. In recent days, a method called SIFT and its improved versions have been introduced to detect this forgery [7, 8, 9, 10], which base on the pixels matching. While this method still has some faults since not all forgery regions are full of feature points and eigenvectors have high dimensions, and the process of matching need much more time. In addition, the image segment and region growing will be applied .These also increase the difficulty of detection. Facing the various forgery methods, it is hard to detect with one or two methods, we must depend on the synthesized method. Our future work is to focus on the new detection for copy-scale-duplication.

Reference

[1] Fridrich, A.J., Soukal, B.D., Mukluks, A.J.: Detection of Copy-Move forgery in digital images. In: Proceedings of Digital Forensic Research Workshop, pp. 5–8 (August 2003)

[2] Lukas, J., Fridrich, Goljan, M.: Digital camera identification from sensor pattern noise. IEEE Transaction on Information Forensics and Security 1(2), 205–214 (2005)

[3] Popescu, A.C., Farid, H.: Exposing digital forgeries in color filter array interpolated images. IEEE Transaction on Signal Processing 53(10), 3948–3959 (2005)

[4] Popescu, A.C., Farid: Exposing digital forgeries by detecting duplicated image regions. Department of Computer Science, Dartmouth College, Technical Report TR 2004-515, Dartmouth College, USA (2004)

[5] Luo, W.Q.: Robust Detection of region duplication forgery in digital image. In: Conf.-pattern Recognition, ICPR 2006, pp. 746–749 (2006)

[6] Wu, Q.: Detection of Copy Forgery Regions in the Image Based on Wavelet and Singular Value Decomposition. Journal of Chinese Computer Systems 4(29), 730–733 (2008)

[7] Lian, S.G., Zhang, Y.: Multimedia forensics for detection forgeries. In: Peter, S., Mark, S. (eds.) Handbook on Communications and Information Security, pp. 801–820. Springer (2010)

[8] Ye, S.M.: Detecting digital image forgeries by measuring inconsistencies of blocking artifact. In: Conf. Multimedia and Expo., pp. 12–15. IEEE Internet (2007)

[9] Pan, Y.P.: Detecting image region duplication using SIFT features. In: Conf-acoustics Speech and Signal Processing, pp. 1706–1709 (2010)

[10] Irene, A.: Geometric tampering estimation by means of a SIFT-based forensic analysis. In: Conf-acoustics Speech and Signal Processing, pp. 1702–1705 (2010)