An Algorithm for Asymmetric Clipping Detection Based on Parameter Optimization

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Abstract. Asymmetric clipping of digital images is a common method of image tampering, and the existing identification techniques of which are relatively meager. Camera calibration technology is an important method to determine the tampering of asymmetric cutting, but the proposed algorithm has made too many assumptions on the internal parameters matrix of the camera, resulting in some error. This paper presents a parameter optimization algorithm based on camera calibration: by keeping the four parameters in the original camera's five internal parameters, after approximate processing, to achieve that a single picture contains no coplanar of the two regular geometric figures can calculate the coordinates of the principal point, and as a basis for the image forensics of the asymmetric cutting tampering. The experimental results show that the proposed algorithm can effectively estimate the camera parameters, the application scope and accuracy can be improved greatly, and can accurately detect the image tampering behavior of asymmetric clipping.

Keywords: Blind forensics · Regular geometric figures · Parameter optimization · Camera calibration · Asymmetric clipping

1 Introduction

With the development of the Internet and the popularity of image processing software, digital image transmission and tampering are becoming more convenient. The means of image tampering–like fuzzy retouching [1]; splicing; copy-move; double JPEG compression; cutting and other means–make the authenticity of the image suffered serious damage, while bringing some political, military, cultural, academic and other aspects of the impact. As a result, our image forensics work is facing challenges.

Image forensics has made some progress in image source authentication [2]; copy-move [3]; splicing [4]; double JPEG compression [5]; etc. Forensics techniques based on computer vision [6] and depth learning [7] have begun to emerge.

Camera calibration technology [8] is an important tool in computer vision. Through the image contains the known geometric shape of the object it can get the camera's internal and external parameters, thereby the image asymmetric cutting tampering

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behavior can be identified. In the past, the algorithm based on camera calibration generally needs to measure the actual size of the calibrated object. However, this greatly limits the scope of the algorithm. The optimization algorithm proposed by us do not need to know the size of the calibration object, it is only necessary to have two or more non-coplanar calibrations in the image to obtain the internal parameters and the external parameters of the camera. By estimating the difference in camera parameters, we can achieve the identification of the authenticity of the image.

The paper is organized as follows: Sect. 2 describes the camera imaging process. Section 3 gives the idea of parameter optimization method to extract evidence of image tampering, while experimental results and conclusion are given in Sects. 4 and 5, respectively.

2 Backgrounds

A basic model of the camera's imaging process is the pinhole model. The basic pinhole model can be understood as a mapping from a three-dimensional continental space to a two-dimensional continental space. The object of the world coordinate system can be transformed into an object of the image coordinate system through a rigid body transformation plus a projection transformation. The transformation from the three-dimensional world coordinate system to the image two-dimensional coordinate system is as follows:

$$x = \lambda \boldsymbol{A} X_c = \lambda \boldsymbol{A} R X_w \tag{1}$$

$$\boldsymbol{A} = \begin{bmatrix} \alpha & \gamma & u \\ 0 & \beta & v \\ 0 & 0 & 1 \end{bmatrix} \tag{2}$$

Where x represents the point in the two-dimensional image coordinate system, λ represents the scale of the transformation, and $\boldsymbol{A}$ is the 3×3 order projection matrix, which is also called the camera internal parameters, with (u, v) the camera's principal point coordinates (for normal images, the coordinates of the principal point are the center of the image), α and β the scale factors in image u and v axes, and γ is the parameter describing the degree of skew of the camera CCD and the corresponding image coordinates. Besides, X_C is a point in the camera coordinate, with R the 3×4 rigid spatial transformation matrix which is also called the extrinsic camera parameters, and X_W represents a world point in the world coordinate.

In order to facilitate the calculation, the model can be further simplified. In the corresponding point selection, we often select the point in the same plane, then the camera's external parameter matrix R can be reduced to 3×3 order, and there:

$$x = \lambda \boldsymbol{A} X_c = \lambda \boldsymbol{A} R X_w = H X_w \tag{3}$$

Where H is a 3×3 homography matrix. If define $H = [h_1, h_2, h_3]$ and $R = [r_1, r_2, t]$, we have (4)

$$[h_1 \quad h_2 \quad h_3] = \lambda \boldsymbol{A}[\boldsymbol{r}_1 \quad \boldsymbol{r}_2 \quad \boldsymbol{t}] \tag{4}$$

Where r_1 and r_2 is the orthogonal vector for the unit, so there are $r_1^T r_1 = r_2^T r_2 = 1$, and $r_1^T r_2 = 0$. Then, two constraints of the camera's internal parameters are obtained:

$$h_1^T \boldsymbol{A}^{-T} \boldsymbol{A}^{-1} h_2 = 0 \tag{5}$$

$$h_1^T \boldsymbol{A}^{-T} \boldsymbol{A}^{-1} h_1 = h_2^T \boldsymbol{A}^{-T} \boldsymbol{A}^{-1} h_2 \tag{6}$$

If there are only four unknown parameters in $\boldsymbol{A}$, it can be seen from the literature [9] that the two sets of calibrators that are not coplanar in the image can obtain two unrelated monocritical matrices, which can be substituted into Eqs. (5) and (6), so the four parameters of $\boldsymbol{A}$ can be obtained.

3 Asymmetric Clipping Detection

The principal point is an important part of the camera's internal parameters, reflecting the important geometric features of the image. If the image is tampered with asymmetric cutting, the center of the image will be offset. According to the relationship between the image center and the principal point, you can determine whether the image has experienced the image asymmetric cutting tampering from the location of the principal point.

3.1 The Estimate of Homography Matrix

The estimate of homography matrix is an important step to solve the problem of computer vision, which determines the accuracy of the internal parameters of the camera. The paper [8] introduced Zhang Zhengyou's calibration method, using the corresponding size of the board to estimate the homography matrix. R-Hardey in the paper [6] described the situation of various camera models and the corresponding method of estimating the homography matrix in detail. In [10], the human eye in the image is modeled as a calibrator, and the homography matrix is obtained without relying on a known size. In the case of the image contains several rules objects, the estimation of the homography matrix can be realized in the paper [9].

However, for a single natural image, there is often no human face and chess board and other fixed objects. Besides, the size of the object in the image is also difficult to obtain, which brought challenges to finding evidence for single image tampering. In the case where the size of the object in the image is unknown, the method of image cropping need to be further optimized.

3.2 Estimating Camera Parameters Using Optimization Methods

The paper [9] implements the method of using the regular objects in the single image to realize the image tamper identification, but makes too many assumptions on the internal parameter matrix. The paper [9] make the assumption that α and β are equivalent, greatly reducing the accuracy of the camera parameters.

This paper solves the problem of too many hypotheses to the internal parameters in the paper [9]. We remove the assumption that α and β are equivalent, after some approximation, the principal points can be obtained by using the regular graphs that are not coplanar in the single image. Determine whether the image has experienced the asymmetric cutting tampering through the offset of principal point. Result in a wider range of the scope of the camera as well as improving the accuracy of the solution of the principal point. The corresponding parameters are optimized as shown in Fig. 1.

$$\boldsymbol{A} = \begin{bmatrix} \alpha & 0 & u \\ 0 & \alpha & v \\ 0 & 0 & 1 \end{bmatrix} \longrightarrow \boldsymbol{A} = \begin{bmatrix} \alpha & 0 & u \\ 0 & \beta & v \\ 0 & 0 & 1 \end{bmatrix}$$

Fig. 1. Parameter optimization

The specific algorithm is as follows:

Define

$$\begin{aligned} B = \boldsymbol{A}^{-T}\boldsymbol{A}^{-1} &= \begin{bmatrix} B_{11} & B_{12} & B_{13} \\ B_{21} & B_{22} & B_{21} \\ B_{31} & B_{32} & B_{33} \end{bmatrix} \\ &= \begin{bmatrix} \left[\frac{1}{\alpha^2}\right] & -\frac{\lambda}{\alpha^2\beta} & \frac{v\lambda - u\beta}{\alpha^2\beta} \\ -\frac{\gamma}{\alpha^2\beta} & \frac{\gamma^2}{\alpha^2\beta^2} + \frac{1}{\beta^2} & -\frac{\gamma(v\gamma - u\beta)}{\alpha^2\beta^2} - \frac{v}{\beta^2} \\ \frac{v\gamma - u\beta}{\alpha^2\beta} & -\frac{\gamma(v\gamma - u\beta)}{\alpha^2\beta^2} - \frac{v}{\beta^2} & \frac{(v\gamma - u\beta)^2}{\alpha^2\beta^2} + \frac{v^2}{\beta^2} + 1 \end{bmatrix} \end{aligned} \tag{7}$$

B is a symmetric matrix,

Define

$$b = \begin{bmatrix} B_{11} & B_{12} & B_{22} & B_{13} & B_{23} & B_{33} \end{bmatrix}^T \tag{8}$$

Define the i-th column vector of H be expressed as

$$h_i = \begin{bmatrix} h_{i1} & h_{i2} & h_{i3} \end{bmatrix}$$

Then we have:

$$h_i^T B h_i = V_{ij}^T b \tag{9}$$

$$V_{ij} = \begin{bmatrix} h_{i1}h_{j1} & h_{i1}h_{j2}+h_{i2}h_{j1} & h_{i2}h_{j2} & h_{31}h_{j1}+h_{i1}h_{j3} & h_{i3}h_{j2}+h_{i2}h_{j3} & h_{i3}h_{j3} \end{bmatrix}$$

Thus, Eq. (4) can be written in the form of b:

$$\begin{bmatrix} V_{12}^T \\ V_{11}^T - V_{22}^T \end{bmatrix} b = 0 \tag{10}$$

If there are N images in the case, we have:

$$Vb = 0 \tag{11}$$

Where V is a 2N $\times$ 6 matrix, and if N is greater than or equal to three images, b can be solved (with a scale factor), so that five internal parameters can be obtained. However, we are based on a map of non-coplanar rules of the object to find the coordinates of the principal point, so need a certain approximation. γ will be approximately equal to 0, still retain α and β, then a total of four unknown, theoretically can be solved. Thereby B_{12} = 0, $B_{33} = \frac{u^2}{\alpha^2} + \frac{v^2}{\beta^2} + 1$, B_{33} has a quadratic term, then it is difficult to simplify. In the actual calculation, it is found that the value $\frac{u^2}{\alpha^2} + \frac{v^2}{\beta^2}$ is close to zero, so B_{33} will be approximately equal to 1.

Define

$$b = \begin{bmatrix} B_1 & 0 & B_2 & B_3 & B_4 & 1 \end{bmatrix}^T \tag{12}$$

Then Eq. (10) can be written

$$\begin{bmatrix} v_{11} & v_{12} & v_{13} & v_{14} & v_{15} & v_{16} \\ v_{21} & v_{22} & v_{23} & v_{24} & v_{25} & v_{26} \end{bmatrix} \mathrm{b} = 0$$

Further simplification, $\begin{bmatrix} v_{11} & v_{13} & v_{14} & v_{15} \\ v_{21} & v_{23} & v_{24} & v_{25} \end{bmatrix}$ with the D matrix to save, and $\begin{bmatrix} -v_{16} \\ -v_{26} \end{bmatrix}$ With the v matrix to save. So we get the following formula

$$\begin{bmatrix} v_{11} & v_{13} & v_{14} & v_{15} \\ v_{21} & v_{23} & v_{24} & v_{25} \\ \cdots & \cdots & \cdots & \cdots \\ v_{n1} & v_{n3} & v_{n4} & v_{n5} \end{bmatrix} \mathrm{b} = \begin{bmatrix} -v_{16} \\ -v_{26} \\ \cdots \\ -v_{n6} \end{bmatrix}$$

Which is $Db = v$. Using the least squares method to calculate the b matrix, then we solve b, and $u = -B_3/B_1$, $v = -B_4/B_2$ can be obtained from the equation.

4 Experiment and Analysis

4.1 Error Analysis

In order to reduce the error caused by the model, we use a group of (200 photos) with no coplanar regular graphics image as a test sample. Estimating the principal point of the image using the proposed parameter optimization algorithm, and normalize the coordinates of the principal Point. The obtained principal point abscissa can basically fall within 20% of the image width of the radius of the central area.

It can be seen from Fig. 2 that the calculated coordinates of the principal points can fall near the center of the image. The experiments in [9] are also based on 0.2 for the radius, but this method estimates the coordinates of the principal points more accurately, the principal distribution of the region is more concentrated, and with less error.

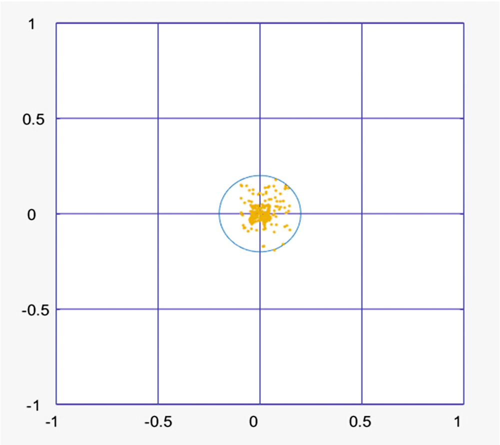
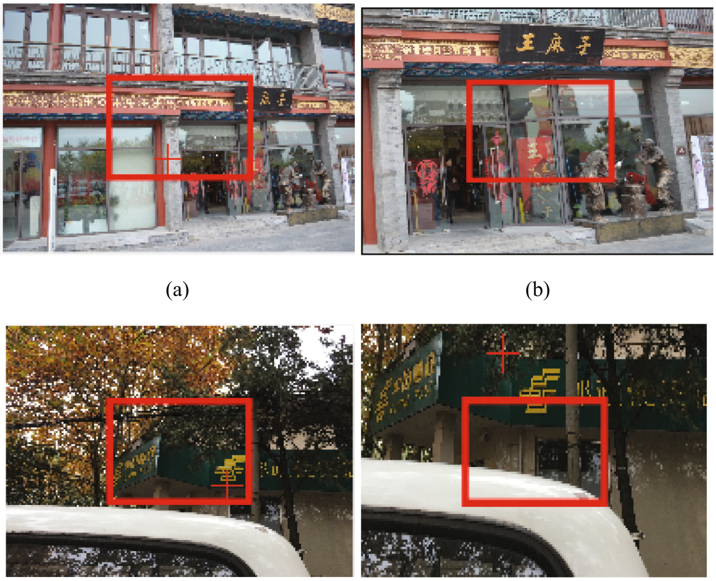


Fig. 2. Estimation of the principal point

4.2 Detection Effect

In Fig. 3 there are two sets of images (a), (c) and (b), (d). (c) is (a) cropped, and (d) is (b) cropped. Each of the images contains a number of regular geometries (text, rules of the decorative patterns, trademarks, etc.) that can be used as a marker for image cutting evidence. For example, the regular walls and the words in Fig. 3, according to the criterion of wall building and the correspondent typeface on the Internet, can be used to identify the worldly coordinate of the object. In addition, Fig. 3(b) has a significant postal logo icon, since the icon rules and the proportion is known, it can be used as an identification of tampering.



(a) (b) (c) (d)

Fig. 3. Example image

This method requires two or more non-coplanar regular geometries to determine the single matrix, in addition, through the camera's internal parameter optimization, the accuracy rate has improved greatly. The rectangular box in the image takes 20% of the length of the image as the edge, and the intersection of the red crosses in the rectangle as the position of the principal point. It can be seen from (a) that the principal point of the image falls within the rectangular box, but the principal point of the cropped image (c) falls directly on the outside of the image, the detection accuracy of which is much higher than that of the paper [9]. This result can also be applied to figure (b), the principal point of the original image falls within the square area, after being cropped to image (d), the principal point ran out of the rectangular red box, obviously deviated from the image center, by that we can say the image (d) has experienced asymmetric cutting tampering.

5 Conclusion

It is a prevalent behavior that the tampering of the asymmetric image cutting. In this paper, a method to detect the asymmetric clipping and tampering behavior in digital images is proposed by using the method of camera calibration. Compared to the past method of camera calibration, the algorithm in this paper does not depend on the modeling of objects and the premise of fixed size, the applicable camera range of the algorithm is greatly improved. In addition, the accuracy of the coordinates of the principal points is improved, hence realizing the evidence-obtain process of tampering behavior of the asymmetric cropping image. It can be seen from the experimental results that the proposed method can effectively detect the tampering behavior of asymmetric cropping images. But for the symmetry of cutting behavior, the effectiveness of the method is to be improved for the future focus of the research.

References

1. Bharati, A., Singh, R.: Detecting facial retouching using supervised deep learning. IEEE Trans. Inf. Forensics Secur. **11**(9), 1903–1913 (2016)
2. Ke, Y., Shan, Q., Qin, F., Min, W.: Image recapture detection using multiple features. Int. J. Multimedia Ubiquit. Comput. **8**(5), 71–82 (2013)
3. Ardizzone, E., Bruno, A., Mazzola, G.: Copy-move forgery detection by matching triangles of key points. IEEE Trans. Inf. Forensics Secur. **10**(10), 2084–2094 (2015)
4. El-Alfy, E.S.M., Qureshi, M.A.: Combining spatial and DCT based Markov features for enhanced blind detection of image splicing. Formal Pattern Anal. Appl. **18**(3), 1–11 (2014)
5. Meng, X., Niu, S.: Technology of digital image tampering based on double JPEG compression. In: National Conference on Information Hiding and Multimedia Information Security (2010)
6. Guo, C., Hong, Y.: Automatic camera calibration method using checkerboard target. J. Comput. Eng. Appl. **52**(12), 176–179 (2016)
7. Zhang, Y., Win, L.L., Goh, J., Thing, V.L.L.: image region forgery detection: a deep learning approach. In: Proceedings of the Singapore Cyber-Security Conference (SG-CRC) (2016)
8. Zhang, Z.: A flexible new technique for camera calibration. IEEE Trans. Pattern Anal. Mach. Intell. **22**(11), 1330–1334 (2000)
9. Meng, X., Niu, S.: Asymmetric crop detection algorithm based on camera calibration. J. Electron. Inf. Technol. **34**(10) (2012)
10. Johnson, M., Farid, H.: Detecting photographic composites of people. In: 6th International Workshop on Digital Watermarking, Guangzhou, China, vol. 5041, pp. 19–33 (2007)

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