Image Splicing Recognition using Lens Radial Distortion Based on Line Calibration

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Abstract— Image splicing may be a common variety of image forgery. This type of changes sometimes doesn't leave visual clues of pasting. In recent works camera characteristics puts consistency across the image has been accustomed establish the originality and integrity of digital pictures. Such constant camera characteristic properties area unit inherent from camera producing processes and area unit distinctive. The set digital cameras area now a days basically equipped with optical spherical lens and this imposes radial distortions on pictures. This aberration is commonly disturbed and fails to make consistent across the image, once a picture is spliced. This paper describes the detection of copy paste operation on pictures by estimating disturbed radial distortion from different parts of the image line-based standardization. The conducted experiments demonstrate the effectualness of our planned approach for the detection of image splicing on each artificial and real image.

Key words: Image Splicing, Lens Radial Distortion, Straight Line Fitting, Structural Images, Camera Calibration

I. INTRODUCTION

As digital technology advances, the need for authenticating digital images, validating their content and detection of forgeries has also increased. Common manipulations on images are copying and pasting portions of the image onto the same or another image to create a composite image. Proving the authenticity and integrity of an image is a challenging task. There are two common properties that an untampered image must have: natural scene quality and natural imaging quality [1]. For example, an image with inconsistency between the light direction and the shadow is not authentic because it fails to satisfy natural scene quality. Any output image naturally inherits the characteristic properties of the acquisition device. An image does not meet the natural imaging quality if different parts of the image do not share consistent characteristics of imaging device. A skilled forger can manage to satisfy the natural scene quality by using sophisticated image editing software but natural imaging quality is very difficult to achieve. This motivates us to take up this research. The aim of this research is to demonstrate that it is possible to use inherent lens aberrations as unique fingerprints in the images for the detection of image splicing. Inconsistency in the degree of lens distortion in different portions of the image leads to the detection of image tampering. It is generally accepted that the optics of most consumer level cameras deviate from the ideal pinhole camera model. Among different kinds of aberrations, lens radial distortion is the most severe. The lens radial distortion causes non-linear geometrical distortion on images. In this paper we propose a novel passive technique (with no watermark or signature) for detecting copy-paste forgery by quantitatively measuring lens radial distortion across the image using line-based calibration. We estimate lens radial distortion from straight edges projected on images. Hence neither calibration pattern nor information about other camera parameter is necessary. Usually a composite image is created not just by weaving different portions of the same or different images, but it is also accompanied by subsequent operations like JPEG compression, contrast/brightness adjustment, color changing, blurring, rotation, resizing etc. to hide the obvious traces of tampering.

Following images showing the spliced image and others are the authentic images. In second image a board is copied from the first image. This type of splicing is done in Photoshop.

Fig. 1: Spliced and Original Images

The remainder of this paper is organized as follows. Section 2 reviews the relevant research on image splicing detection. Section 3 details the background of lens radial distortion and also describes how to estimate lens radial distortion parameter for each detected line segment in the image. Section 4 analyses the effect of lens distortion at various zoom levels, for different cameras and also presents experimental results on the detection of image tampering performed on both synthetic images and real images. Section 5 discusses the limitations of the proposed method and future work. Section 6 concludes the paper.

II. LITERATURE SURVEY

Digital image forensics is emerging as an interesting and challenging field of research [2, 3] recently. Here we present the review of related works on image splicing detection. One of the kinds of image tampering is object removal

where the regions of unwanted objects in an image are replaced by other parts of the same image. This type of operation is called copy-move or region-duplication. Methods in [4-6] are specifically designed to detect region duplication and are all based on block matching. First, the method divides an image into small blocks. Then it extracts the features from each block and hence, identifies possible duplicated regions on comparison. The main difference of these methods is the choice of features Popescu, et al. [5] have employed the principal component analysis (PCA) to reduce the image blocks into a PCA feature vector. Luo et al. [6] have extracted seven features in each block. Their experimental results demonstrated that the method could resist more post-processing operations. Another kind of image tampering is splicing. Unlike region duplication, image splicing is defined as a simple joining of fragments of two or more different images. Several researchers have investigated the problem of splicing based on statistical properties of pixels (called pixel-based techniques) and camera characteristics (called camera-based techniques). Now, let us briefly review the literature on both techniques.
Farid et al. [8] have noticed that the color images taken from a digital camera have specific kind of correlations among the pixels, due to interpolation in the color filter array (CFA). These correlations are likely to be destroyed, when an image is tampered. They have showed that the method can reasonably distinguish between CFA and non-CFA interpolated portions of images even when the images are subjected to JPEG compression, additive noise or luminance non-linearity. But they have not discussed splice detection, when portions of different images with same CFA interpolation technique are spliced together as a composite image. Lukas et al. [10] have presented an automatic approach for the detection of tampered regions based on pattern noise, a unique stochastic characteristic of imaging sensors. The regions that lack the pattern noise are highly suspected to be forgeries. The method works in the presence of either the camera that took the image or when sufficiently many images taken by that camera are available. However this is always not possible. A semi-automatic method for the detection of image splicing based on geometry invariants and camera characteristic consistency have been proposed by Hsu [11].

III. LENS RADIAL DISTORTION

Virtually all optical imaging systems introduce a variety of aberrations into an image due to its imperfections and artifacts. Lens distortion is one such aberration introduced due to geometry of camera lenses.

A. Background of Lens Radial Distortion:

Unlike extrinsic factors, intrinsic factors are due to camera characteristics and are specific constants to a camera, e.g. focal length, imaging plane position and orientation, lens distortion, aspect ratio etc. These are independent of position and nature of the objects captured. Lens distortion is deviation from rectilinear projection; a projection in which straight lines in a scene remain straight in an image. However, in reality almost all lenses suffer from small or large amounts of distortion. Lens radial distortion is the dominating source of mapping errors especially in inexpensive wide-angle lenses because wide-angle lens is shaped to allow a larger field of view. Due to the shape of the lens magnification and focus is not isotropic resulting in unwanted distortions. Lens radial distortion deforms the whole image by rendering straight lines in the object space as curved lines on the film or camera sensor. Radial distortion is a non-linear transformation of the image increasing from the centre of distortion to the periphery of the image. The centre of lens distortion is a point somewhere close to the centre of the image, around which distortion due to the shape of the camera lens is approximately symmetrical. Fig. 1 shows an image of a grid and 'r' is the radius of grid. Two of the most common distortions are barrel (k>0) and pincushion (k<0) distortions (shown in fig. 2a & 2b), where k is the distortion parameter which indicates the amount of lens radial distortion. 'r`' in fig. 2 is the deformed radii of the grid due to distortions.

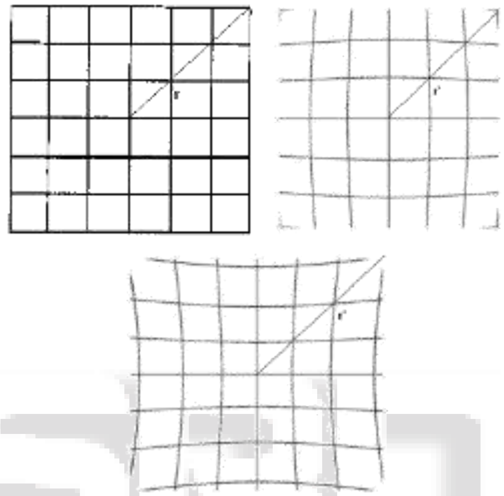

Fig. 2: Are the Deformed Radii of the Grid Due To Distortions

Fig. 1 No distortion fig. 2(a) Barrel distortion Fig 2.(b) Pincushion distortion Fig 2 showing the distorted patterns for images.

It is evident from fig. 2a & 2b that the amount of distortion increases with distance from centre of image to the periphery of image. We have found that this correlation among different portions of the image is disturbed in spliced images. In order to prove the integrity of an image, in this paper, we look for the consistency among the lens radial distortion parameters which are estimated from different regions of an image. This source of information is very strong, provided 3D lines are projected on the image. Thus the proposed technique works on images of city scenes, interior scenes, aerial views containing buildings and man-made structures.

B. Measuring Radial Distortion of Lenses:

The lens radial distortion model composed as limitless arrangements r , as given below:

$$r_u = r_d(1 + k_1 r_d^2 + k_2 r_d^4 +) \qquad (1)$$

with $r_u = \sqrt{x_u^2 + y_u^2}$

and $\boldsymbol{r_d} = \sqrt{\boldsymbol{x_d^2} + \boldsymbol{y_d^2}}$

with $r_u = \sqrt{x_u^2 + y_u^2}$ and $r_d = \sqrt{x_d^2 + y_d^2}$

r_u and r_d are undistorted and distorted radii respectively.Radius is the radial distance $r = \sqrt{x^2 + y^2}$ of a point x,y from the centre of distortion. From (1) it follows that:

$$r_u = \sqrt{x_u^2 + y_u^2}$$

$$x_u = x_d(1 + k_1 r_d^2 + k_2 r_d^4 + \cdots) \quad (2)$$

$$y_u = y_d(1 + k_1 r_d^2 + k_2 r_d^4 + \cdots) \quad (3)$$

Middle of contortion is taken as focus of picture. The primary request spiral symmetric mutilation parameter is adequate for sensible exactness. In this way the polynomial bending model in (2) and (3) may be streamlined as

$$x_u = x_d(1 + k_1 r_d^2) \quad (4)$$

$$y_u = y_d(1 + k_1 r_d^4) \quad (5)$$

The parameter k_1 has dominant influence on the kind of radial lens distortion. If $k_1 > 0$, distortion is barrel and if $k_1 < 0$, distortion is pincushion.

C. *Proposed Approach:*

Portions of an image are correlated with each other with respect to the imaging device. Such correlations will be disturbed in spliced images. An intrinsic camera parameter viz., lens radial distortion is used for the detection of image splicing. Inconsistency in the degree of lens radial distortion across the image is the main evidence for splicing operation. In this section, a novel passive technique is described for detecting copy-paste

forgery by quantitatively measuring lens radial distortion from different portions of the image using line-based calibration. Line-based calibration of lens radial distortion can be divided into three steps:

1) Detection of edges with sub-pixel accuracy.
2) Extraction of distorted line segments.
3) Estimation of k_1 for each distorted line in an image.

1) Detection of Edges with Sub-Pixel Accuracy:

The first step of the calibration consists of detecting edges from an image. Since image distortion is sometimes less than a pixel, there is a need for an edge detection method with sub-pixel accuracy. We used the edge detection method proposed in [13], which is a sub-pixel refinement of the classic non-maxima suppression of the gradient norm in the direction of the gradient.

2) Extraction of Distorted Line Segments:

This calibration method relies on the constraint that straight lines in 3D must always project as straight lines in the 2D image plane, if the radial lens distortion is compensated. In order to calibrate distortion, we must find edges in the image which are most probably projections of 3D segments. Because of the distortion, a long segment may be broken into smaller segments. By defining a very small tolerance region, we can extract such distorted line segments as shown in fig. 3.

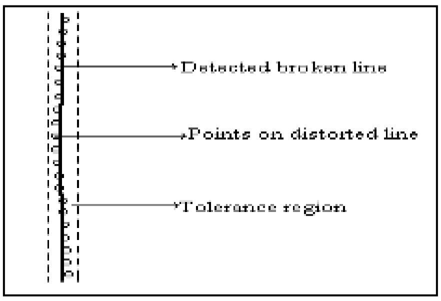

Fig. 3: Detection of Broken Line Segments within the Tolerance Region

Perturbations along the lines may be generated due to low resolution of the image. Such distracted or perturbed line segments must be rejected even within the tolerance region.

3) Estimation of K_1 for Each Distorted Line in an Image:

Measure the degree of distortion in terms of distortion parameter k_1 for each distorted line in the image. In order to measure the absolute deviation of a distorted line from its undistorted line, the points on a distorted line segment are used to fit a straight line using linear regression. From eq. (4) and eq. (5), all '*n*' distorted points $P_{d,i}=(x0_{d,i}\ y_{d,i})$ of the selected curved line are mapped to the undistorted points $p_{u,i}=(x_{u,i}\ y_{u,i})$ where $(1 \le i \le n)$ as follows:

$$x_{u,i} = x_{d,i}(1 + k_1 r_{d,i}^2) \quad (6)$$

$$y_{u,i} = y_{d,i}(1 + k_1 r_{d,i}^2) \quad (7)$$

All 'n' undistorted points $p_{u,i}$ should now lie on a straight line. Thus, an associated straight line 'L_n' is represented in Hesse's normal form, it has three unknowns n_x,n_y and d_0 :

$$L_n : \begin{pmatrix} n_x \\ n_y \end{pmatrix}^T \begin{pmatrix} x \\ y \end{pmatrix} - d_0 = 0 \quad (8)$$

$$\varepsilon_i = \begin{pmatrix} n_x \\ n_y \end{pmatrix}^T \begin{pmatrix} x_{u,i} \\ y_{u,i} \end{pmatrix} - d_0 \quad (9)$$

From equation no (6) and (7)

$$\varepsilon_i = \begin{pmatrix} n_x \\ n_y \end{pmatrix}^T \begin{pmatrix} x_{d,i}(1 + k_1 r_{d,i}^2) \\ y_{d,i}(1 + k_1 r_{d,i}^2) \end{pmatrix} - d_0 \quad (10)$$

Where k_1 is selected to minimize $\sum_{i=1}^{n} \varepsilon_i^2$

This cost function is a non-linear function of $x_{d,i}$ *and* $y_{d,i}$ of a curved line or distorted line. The deviation of points $(x_{d,i}\ y_{d,i})$ from their original positions $(x_{u,i}\ y_{u,i})$ is used to estimate the amount of distortion. The distortion error is the sum of squares of distances from the points to the straight line. To estimate distortion parameter k_1 the sum of squares is minimized using the iterative Levenberg-Marquardt method through lsqnonlin function found in MATLAB. Thus we obtain unique k_1 for each distorted line segment in an image depending on the amount of straight line. To estimate distortion parameter k_1 the sum of squares is minimized using the iterative Levenberg-Marquardt method through lsqnonlin function found in MATLAB. Thus we obtain unique k_1 for each distorted line segment in an image depending on the amount of distortion.

IV. EXPERIMENTAL SETUP

Three sets of experiments were performed. The first set of experiments aims at technical investigation and calibration of lens radial distortion for different consumer level compact digital cameras. The second set of experiments conducted on synthetic images to show how to use radial distortion parameter as a feature to detect image splicing.

The third set of experiments study the performance of proposed features on real images.

A. Analysis of Lens Radial Distortion for Different Cameras:

To analyze the behavior of intrinsic radial distortion parameter across the image, we have used 3 digital cameras of recent models from four different manufacturers. The configurations of the cameras are given in table 1.

Camera model	Focal length	megapixel	Optical zoom	Size of images
Sony W620	28-140	5 mp	5x	~6 MB
Sony x200	25-250	14mp	14x	~6.7 MB
Nikon S6200	25-250	10 mp	10x	~7 MB
Note- all focal length are equal to 35 mm film camera				

Table 1: Properties and List of the Cameras Used

Fig. 4 shows the checker-board with square grids, generated manually without any distortions. Fig. 5 shows the extracted straight lines from fig. 4. The lens radial distortion parameter k1 is computed for each straight line (ref section 3.3) and is reported zero for all straight lines and the same is shown as a graph in figure. All through the experiments, it is assumed that the image centre as (0,0) and the horizontal and vertical coordinates are normalized so that the maximum of the dimensions is in the range (-1,1). Most consumer digital cameras are equipped with an optical zoom lens. The lens radial distortion parameters change with focal length, which usually varies from barrel at the wide end to pincushion at the tele end. In this section we investigate the impact of optical zoom on the behavior of radial distortion parameter across the image.

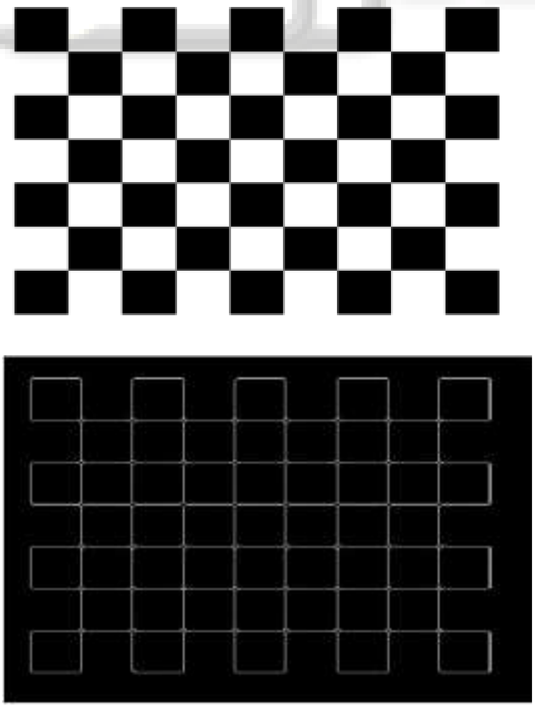

Fig. 4: Standard Chess Board Images

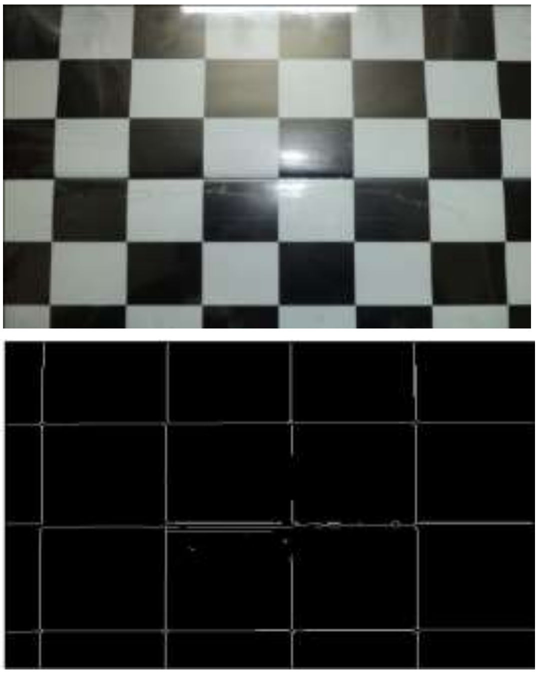

Fig. 5: Images Obtained By Sony W620 Camera At 1x Zoom

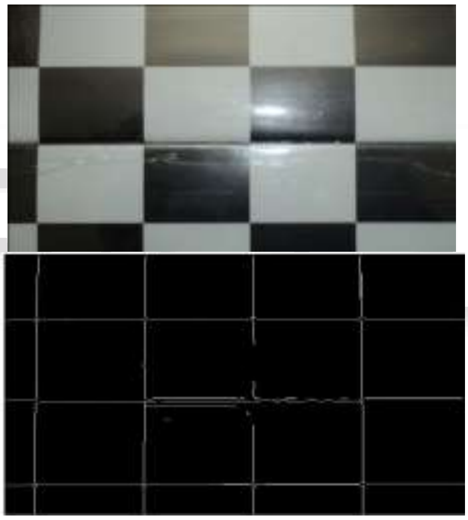

Fig. 6: Images Obtained By Sony W620 Camera at 2x Zoom

Fig. 7: Images Obtained By Sony W620 Camera at 3x Zoom

To study the actual behavior of radial distortion parameter k_1 across the image, images of the same scene are acquired from different cameras. The checker board is captured, approximately with same distance, position and orientation of the camera. The images were taken with no flash, auto-focus, JPEG format and other default settings. The sample images captured by Sony DSC-W620 camera with different zoom levels is shown in fig. 5. fig. 6 and fig 7 is the corresponding edge images of each image in fig. 4. Since the radial distortion is approximately symmetric we have drawn the graph of k_1 for vertical lines which lies in the right of image centre. It is clear that no camera is ideal. All cameras have noticeable amount of radial distortion. It is also evident from the graph that the degree of radial distortion increases with the distance from centre of the image. We can also observe that the radial distortion parameter changes with zoom and most of the cameras vary from barrel at the wide end to pincushion at the tele end.

B. Experiments on Synthetic Images:

In this section we describe, how to use lens radial distortion parameter for the detection of image splicing. If two image regions belong to the same image (untampered) then the radial distortion of extracted line segments should behave as expected. That is lines that are more or less equidistant will suffer from more or less equal amount of radial distortion. Also radial distortion is uniform, barrel or pincushion. Usually the composites are created in three ways:

1) Image splicing on the same image (copy-move forgery)
2) Two or more images of the same camera (may be captured at different zoom) are used to create a composite image.
3) Two or more images of the different cameras (irrespective of the camera make or model) are used to create a spliced image.

Hence, we used three different cameras, in which two are from same manufacturer. Table 2 shows the distances (column 2) of straight lines from the image centre and its corresponding value Similar observations on k1 were already es of k_1 (column 3). This consistency will be disturbed in case of copy-move or copy-paste forgery. Inconsistency of lens radial distortion parameter be detected if one of the two following conditions is not met: (a) Amount of radial distortion is symmetric and increases with the distance from centre of the image towards peripherry and (b) Sign of k1 should be same for all lines throughout the image.

Following image in fig 8.1(a) and (b) showing the original image of the wall and the extracted image of the wall. And in fig 9.(a) and (b) showing the forged image of the wall and the extracted output of the forged image. Table 2 showing the distortion parameter k_1 values of selected thresholded line segments. this table showing the distortion values are in a similar given pattern as per given above, this values are in a increasing order from centre of distortion towards periphery of the images.

Fig 9.(a) showing the forged image of the wall having added part of the board form other images capture at different zoom levels with other camera. This part is added showing the distorted segments with different values changed at region. Because of this pasted part over the one another corresponding edges would change to barrel (pincushion) where as the actual distortion in untampered image would have been pincushion (barrel).

(A)

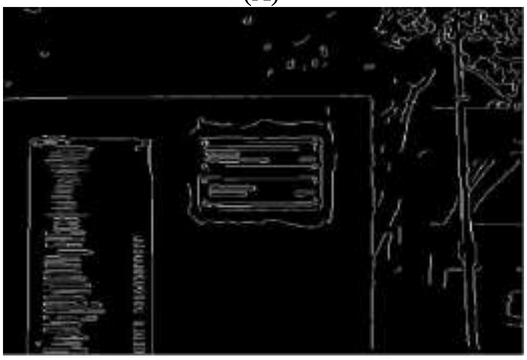

Fig. 8: (A) Original Images and (B) Extracted Edges

Straight line no.	Distortion parameter k_1
1	0.0055
2	0.0023
3	-0.0013
4	0.0026
5	0.0060

Table 2: For the K_1 Selected Line from Left to Right

Following table 3 shows the values at a line 4 and 5 are disturbed that are showmn in a bold letters. This implies the detected inconsistency of type (a) in forged image. Thus splicing has been successfully recognised.

Fig. 9: (A) Forged Image And (B) Extracted Edges Image.

Straight line no.	Distortion parameter k_1
1	0.01450
2	0.0112
3	-0.0019
4	0.1911
5	-0.1502

Table 3: For the K1 Selected Line from Left to Right

In real cases, the creation of composites is commonly accompanied with subsequent operations like JPEG compression, contrast/brightness adjustment, color changing, blurring, rotation, resizing etc. to hide the obvious traces of tampering. Since the proposed splicing detection method works on images consisting of straight edges, contrast, brightness and color manipulations will not affect edge detection, unless the object color and the background color are indistinguishable. It is evident from the above experiments that the proposed approach is robust to rotation, as distortion is same even if lines are rotated. We observed that JPEG compression, blurring and resizing operations affects on the performance of the proposed method.

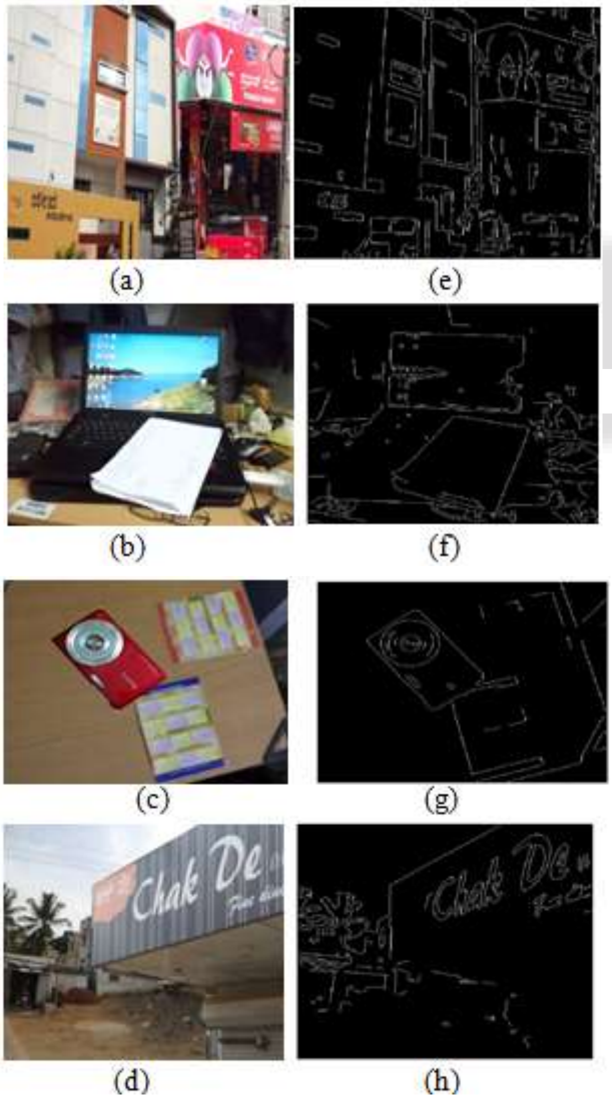

Fig. 10

The non-availability of the suitable data set for examining the proposed method led us to create our own Spliced Image Data Set (SIDS). In order to compute the splice detection rate, we have created 100 spliced images from 300 authentic images. Authentic images were taken with our 2 consumer level compact digital cameras and 20 images are downloaded from internet. All images were taken from each of cameras in JPEG format and downloaded with dimensions ranging from 550x450 to 3276x2064. These images mainly contain indoor scenes like tables, library, photo frames, laptops, boards, etc. Some images contain outdoor scenes like buildings, shops etc. We created spliced images from the authentic image set using Adobe Photoshop. And for hiding the traces of pasting, some post processing operations like resizing and rotation were performed. As a first step, all distorted line segments from each spliced image are detected.

V. Conclusion

Portions of the image are correlated with each other with respect to the imaging device. Such correlations will be disturbed in spliced images. We have used an intrinsic camera parameter, namely lens radial distortion, for the detection of image splicing. Inconsistency in the degree of lens radial distortion across the image is the main evidence for the detection of spliced images. In this paper we propose a novel passive technique (with no watermark or signature) for detecting copy-paste forgery by quantitatively measuring lens radial distortion from different portions of the image using line-based calibration Experiment in section 4.1 shows that most consumer level digital cameras have small or large amount of lens radial distortion at different zoom levels. Experimental set up in section 4.2 demonstrates how efficiently the lens radial distortion parameter k1 may be used for the detection of image splicing and the experimental results in section 4.3 shows that our method works well in case of real images. The primary contribution of our work is that we examine the use of inherent lens distortion as a unique imposed imprint on the images for the detection of image splicing.

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