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Source Camera Identification Using Interninsic Fingerprints

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Abstract:
The identification of an image acquisition device becomes a very important in digital image forensics. In this paper main focus is on identification of digital camera and provides a new approach of identification. As digital camera uses many components in image generation process such as lens, sensors, CFA (colour filter array) e.t.c. Each component has its unique characteristics that can be known as fingerprints. By extracting that fingerprint identification of digital camera can be done. In this paper identification is done on the basis of sensor noise and CFA unique characteristics. From sensor photo-response non-uniformity (PRNU) is considered because it was introduced by Luk´a˘s et al. [2] for identification of digital camera. So in this work PRNU (Photo Response Non Uniformity) and 12 features from CFA are used. Classification is done by using SVM classifier (Support Vector Machine). Experimental analysis shows that the proposed method has good potential for identification of digital camera.

Key words*: PRNU (Photo Response Non Uniformity), CFA (color filter array), SVM (Support Vector Machine), Digital Image Forensics*

1. Introduction

Digital forensics mainly deals with the digital images. As nowadays due to development in network technologies or we can say that advancement of image processing technologies lead to share, use of digital images in many applications. Due to the use of images in many applications the security of it becomes a very important part. As there are many image editing software that can easily altered digital images. The security of it becomes a very important part. Digital Image Forensic tries to investigate the origin of the image. The source of a digital image can be a digital camera, scanner or any software tools.

There have been studies on watermarks that help us determine whether an image has been altered [11]. It is necessary to embed watermark in an image during image formation. This will make the internal circuit of camera complicated because special processing is required for embedding a watermark and also increase the manufacturing cost. So it was very difficult to identify the source of images. By keeping this problem in mind, the researchers proposed that some features that can be used for better identification such as hardware imperfections or software related fingerprint left by the basic elements of digital camera and known passive blind technique. As these basic elements are considers as backbone of every digital camera. So fingerprints that can be taken from these elements are pattern noise [2], lens radial distortion [12], or sensor dust [13] these are due to the hardware imperfection. Similarly image features such as colour features, image quality features, wavelet domain statistic based features can be used which are known as software related fingerprint. Source camera identification means tries to identify the capturing device i.e. from which camera. Fig1. Shows the basic architecture of digital camera that exhibits some unique fingerprint. Before the detail description of these fingerprints, it is necessary to know the basic working of a digital camera which is explained below

- The lens focuses the light onto the pixel grid of the sensor.
- A next CFA filter which is used to take only light of one specific colour enters the pixel array.
- Sensor use many photodiodes that receive light signal as a input and generation of charge take place due to interaction of photons with silicon which is first amplified and then quantized.
- To obtain a color image the signal is interpolated or demosaiked.
- Finally the color is further adjusted to display correctly on a computer monitor through color correction.

So digital camera can be identified by extracting the fingerprint from its components that means from sensors, CFA etc. e.g. from sensors on the basis of pattern noise [2] and from CFA by extracting the color features [10] it can be identified. Mostly SPN (sensor pattern noise) is preferred because of the advantage of SPN is that it can identify not only camera models of the same make, but also

individual cameras of the same model [2][3]. The deterministic component of SPN is mainly caused by imperfections during the sensor manufacturing process and different sensitivity of pixels to light due to the in homogeneity of silicon wafers [4][8][6]. In this study the combination of hardware imperfections or software related fingerprint are used.

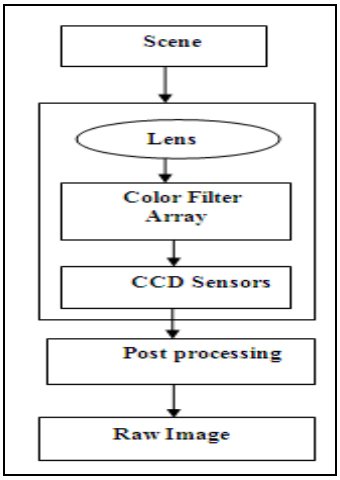

Figure 1.1: Basic elements of digital camera

Their study has been adopted and further modified to identify not only digital camera but also the mobile camera phone [14]. The combination of hardware fingerprint and software related fingerprint can be used for further improvement in the identification process. Similarly this paper uses the combination sensor noise and some of the color features for enhancing the features for classification purpose. Below figure shows the basic extraction process of features from a image.

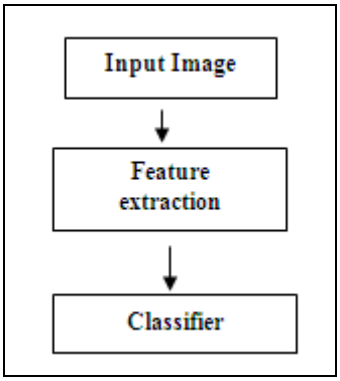

Figure 1.2: Basic extraction process

Input image can be generated from digital camera or from computer. Then extract features from this input image and obviously these extracted features have different characteristics for both computer generated and digital camera images. After that use classifier for classification of computer generated and digital camera image.
This paper will be organized as follows. Section 2 describes the some related work for identification of camera source. The theoretical approach is explained in section 3. Section 4 gives description about the database which is used in this study and shows the experimental result of this study. Conclusion and future work demonstrate by section 5.

2. Related Work

Digital camera can be identified by CFA (color filter array) in which each pixel in the image has only one color component associated with it [9] and interpolation algorithm is used for getting the missing colors values. As these algorithms varies from camera to camera so by identifying so by considering this fingerprint identification of particular digital camera can be done. Image features can also be used for identification of digital camera [10]. As there are many different features such as color feature, quality feature, image quality features and wavelet domain feature. By classifying these features determination of the source of image can be done. Mostly CFA interpolation based methods use to estimate the inter pixel relationship as features for identification of the source of image [21]. This method of identification is quite complex because CFA pattern of an image is not known at receiver. So to reduce the complexity [21] purposed a method of using inter-channel demosaicking/color interpolation traces for identification purpose.
Further approach is based on the pattern noise due to the sensor imperfection. Pattern noise in an imaging sensor is of two types i.e. FPN (Fixed Pattern Noise) and PRNU (Photo Response Non Uniformity). FPN (Fixed Pattern Noise) is caused by dark current which is generated due to the thermal activity of photocathode. Different pixels have their different rate of generation of dark current so this

method similar as to detect defects pixels**.** PRNU (Photo Response Non Uniformity) is due to the variation in the pixels when they are under illumination. Photo Response Non-Uniformity (PRNU) feature is considered as a unique identification of digital camera. Another method purposes that it is not necessary that whole image have a same amount of PRNU. So by keep this point in mind they consider the best part of noise residual image which have highest value of PRNU and discarding another area [19].
As inspired by the uses of sensor imperfection the intrinsic lens aberration can be used as a feature for camera identification. For each image under investigation, parameters from pixel intensities and aberration measurements are obtained [15] and then classifier is used for identification of source of image. Further approach for identify the source of digital image is based on Auto White Balance algorithm. They propose to identify the source camera by approximating the AWB algorithm used inside the camera [16]. Another method is to use tensor decomposition analysis which is applied to extract features of nonlinear operations, which come from both algorithms embedded within camera and operations done by post-software [17]. As digital camera have different characteristics than that of computer generated image. Histogram based identification can be done for discrimination between digital camera generated image and computer generated image. They calculate first calculate the difference image and then take histogram of that image. They observe that computer generated image has a highest peak than that of digital camera captured image [18].

3. Source Camera Identification

Below approach is based on identification of digital camera on the basis of various features that shows characteristics of digital camera. The detailed description of these features is given in below section.

3.1. PRNU (Photo Response Non Uniformity)

Feature obtained from sensor which is the main component of every digital camera [4]. If imaging sensor is illuminated with light in the absence of noise source then the output of imaging sensor will be

$$\text{Output} = Y + YK \quad (1)$$

Where Y is the input light intensity
YK is referred to as PRNU

- To obtained PRNU feature the original image is first subtracting from it's denoised version to get noise residual i.e.

$$W = I_p - F(I_p) \quad (2)$$

Where I_p is the original image
$F(I_p)$ noise free image
W noise residual

- Then calculate reference PRNU from L number of images taken from same camera can be done as

$$K = \frac{\sum_{k=1}^{L} wk\,Ik}{\sum_{k=1}^{L} Ik \times Ik} \quad (3)$$

Where K is the estimation of fingerprint i.e.
PRNU
Ik is the original image
Wk is denoised image of original image

$$Wk = Ik - F(Ik) \quad (4)$$

Where Ik is the original image
L is the number of images used for obtaining
Reference pattern

3.2. Next features are obtained from CFA (color filter array)

Which is also a basic component of digital camera? The measure is based on that

- Three features are obtained from the average value of three RGB channels because of the grayscale assumption which state that the average values in RGB channels of an image should average to gray [10].
- Another feature is obtained by detecting the correlation between three RGB pairs such as RG, RB, GB.
- Next feature is obtained from distribution that can give determine the sensitivity of camera to different intensity levels. This can be done by calculating the pixels values for a number of pixels. the numbers are transferred to neighbor values where neighbor values are sums of each pixel value's neighbor pixel, which was defined as all pixels that have a difference of value of 1 or -1 [10].
- After that calculate the energy pairs ratio which is very important feature because white point correction is important process in digital camera pipeline. So three features can be obtained i.e.

$$E_1 = |G|^2 / |B|^2, \quad (5)$$

$$E_2 = |G|^2 / |R|^2 \quad (6)$$

$$E_3 = |B|^2 / |R| \quad (7)$$

Where E1, E2, E3 are called energy pair ratio

4. Experiments and Result

4.1. Image Database

As identification of digital camera require many images which are captured from same camera. Basically it is very difficult to collect various images which are captured from same camera. In this paper Dresden database is used for collection of that images. Anyone can access this database. It contains many images of various cameras. But in this paper only images from two cameras have been used.

4.2. Experimental Result and Analysis

In order to see the effectiveness of the proposed method in this paper mainly six types of camera's images are used i.e. Samsung**,** Nikon, Olympus, Kodak, Casio and Canon. Dresden data base is used for collection of the images which are captured from same type of cameras. In this paper 100 images for each cameras are used i.e. total 600 images are used for training purpose. In this experiment two types of features are used i.e. Sensor based PRNU feature and CFA based color features.

Extract these features (PRNU and CFA related feature) as explained in section 3 from these images for classification purpose and make a feature set. As support vector machine is a flexible classifier, affording good classification accuracy [22]. So SVM classifier is used for the purpose of classification. First we train the SVM classifier on the basis of this extracted feature set and then extract the same number of features from the test image. Then SVM classifier gives very good result of classification and this result is shown in Table 1.

		Predicted (%)					
		Samsung	**Nikon**	**Kodak**	**Casio**	**Canon**	**Olympus**
Actual (%)	**Samsung**	80.00	0.00	0.00	14.00	0.00	6.00
	Nikon	14.00	76.00	0.00	0.00	10.00	0.00
	Kodak	0.00	9.00	83.00	0.00	8.00	0.00
	Casio	4.00	0.00	0.00	88.00	0.00	8.00
	Canon	0.00	5.00	0.00	3.00	92.00	0.00
	Olympus	15.00	0.00	0.00	0.00	0.00	85.00

Table 1: Confusion matrix

As shown in confusion matrix six cameras was used for identification purpose. Each individual camera have a accuracy which is found to be greater than 75 % i.e. minimum accuracy is 75% and maximum accuracy is 92% which is for canon camera source.

5. Conclusion and Future Work

In this paper the problem of identification of camera is done. As by using the combination of hardware

Imperfections (PRNU feature) or software related fingerprint (CFA related features) gives one possible solution for the problem of identification. As PRNU found to be a unique fingerprint of every

Digital camera. So when this feature is used with combination of other features as in this paper CFA related features are used then this will gave good results from previous methods but accuracy is very much depend upon the feature selection. Basically noise feature depend upon the suitable selection of the denoised filter because it is mainly responsible for capturing the sensor noise. This classification accuracy can further be increase by improving the proposed features.

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