Camera Identification Algorithm Based on Sensor Pattern Noise Using Wavelet Transform, SVD / PCA and SVM Classifier

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Received: 02/Jun/2013 Accepted: 11/Dec/2013

Abstract
Identifying the source camera of an image is one of the most important issues of digital court and is useful in many applications, such as images that are presented in court as evidence. In many methods, the image noise characteristics, extraction of Sensor Pattern Noise and its correlation with non-uniformity of the light response (PNU) are used. In this paper we have presented a method based on photo response non uniformity (PRNU) that provides some features for classification by support vector machine (SVM). Because the noise model is affected by the complexity of the image, we used the wavelet transform to de-noise and reduce edge effects in PRNU noise pattern and also raise the detection accuracy. We also used the Precision processing theory to reduce the image size, then we simplified and summarized the data using the Single Value Decomposition (SVD) Or principal component analysis (PCA). The results show that using two-level wavelet transform and summarized data is more suitable using PCA.

Keywords: Sensor Pattern Noise, Camera Sensor Pattern Noise, Source Camera Identification, Photo Response Non-Uniformity, Wavelet Transform.

1. Introduction

Digital images can be taken by various types of digital cameras. In some applications, it is important to determine the source of a digital image. Since the digital images and videos can be easily fabricated, their contents are not reliable.

Thus identifying the source camera may be useful in judgments about images. Especially the electronic image detection techniques are important in the court. For example, identifying the source tool can determine the main images as evidence.

Identifying the source camera of an image is a complex issue that requires understanding the process of creating a graphic image of a real scene. In particular, it is necessary to know what is real and staged processes that affect the final digital data. In addition, it is necessary to consider the factors that may help to identify the camera. Many detection techniques have been proposed in the scientific literature. In general, most of these techniques work using the sensor noise (unwanted changes that occur in digital signal). This noise remains by digital sensor as a fingerprint in the image at the time of shooting.

In this paper, we first provide a summary of the performed activities, and then present our proposed algorithm. In the second section, we explain the processing stages in a digital camera that causes defects and noise in the image, especially the noise model. The proposed algorithm is described in the fourth section. Then, a detection technique is presented using support vector machine (SVM) that classifies the images into the corresponding camera. The efficiency of procedure is evaluated in the fifth section.

2. Related Works

Several methods have recently been proposed to detect camera. Reference [1] proposes an approach that detects the camera type using the noise correlation related to the Photo Non-uniformity (PNU). In this method, it is necessary to collect a large number of images related to a specific camera to take out an average of their residual noise, so that the camera Sensor Pattern Noise can be obtained. Because the image includes a wide range of noise and we have to nullify the effect of noises and just get the camera Sensor Pattern Noise, thus averaging enables us to achieve this goal. After that, a correlation threshold is used between the camera noise model and the image noise model to identify the source.

Reference [6] tests this method with changed images and the results show that in most cases this method is resistant against changes caused by the image processing functions. Reference [3,5] suggests a new idea for camera

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detection which is based on the collection of some image features. In this method, each image is presented as a vector of numerical features and the source camera can be detected by a classifier.

In some methods, it is necessary to consider some backgrounds (E.g. methods [9-12]), but the methods that are based on Sensor Pattern Noise do not require such assumptions.

The basic problem in the noise model extracted from image is that the extracted noise is not the real Sensor Pattern Noise, because the other random noises are affected by the image edges and complexity. Thus, reference [4] suggests some improvement for the Sensor Pattern Noise In this context, reference [7] finds some image retrieval methods however, this method is also correlation.

In this study, we use wavelet transform to reduce the complexity and the edges of the image. We also use SVD/PCA to reduce the data dimensions. Then, the obtained models are classified by SVM.

3. Digital Camera and Noise Types

In this section, we explain the processing stages that occur in a conventional digital camera and the noise types that enter the image at the time of shooting and are used as a fingerprint to identify the camera.

Light enters into a set of lenses and passes the counter -intuitive filters. Then it can be available to the color filter array (CFA) and considers one of the components of red (R), green (G) and blue (B) in each pixel because the sensor is only capable of leading one color at each pixel. Then an interpolation process is used to estimate the intensity of two other colors for each pixel using neighborhoods. A sequence of image processing operations such as color correction, white balance, gamma correction, image enhancement, and JPEG compression have been done, then the image is placed in the memory space. Some features of this process can be used to identify the type of camera as the sensor pattern noise (SPN), the response function of the camera, re-sampling, color filter array interpolation, JPEG compression and lens aberrations.

Some of these sources of noise are temporary and the others are based on distance and other types of noise are a combination of both.

Noise fluctuates over time indicate the "random" or "temporary" noise. There are three main types of temporary noises in optical and electronic systems: shot noise, thermal noise, and flicker noise. All of them can be observed in image sensors of CMOS and CCD. The noise which appears in the reconstructed image and is fixed in a certain place of the image implies a fixed pattern noise (FPN). Since it is fixed in terms of distance, then can be removed in the dark spots using the signal processing. Initial component (FPN) of in a CCD image sensor is the current non-uniformity of dark spots. This could be due to the time of shooting image or high temperatures. the main sources of FPN in CMOS image sensors are the current non-uniformity of dark spots And differences in the efficiency of an active transistor in a pixel. The important thing about FPN is that the spatial pattern of these changes remains constant. Since the FPN is added to all of the frames or images generated by a sensor and are independent of the light, it can easily be removed by subtracting a dark frame from the image.

A source which is somewhat similar to FPN in terms of properties is called the non-uniform response to light. One of its reasons is the non-uniform size of the active area through which light photons are absorbed. This effect is linear. PRNU is the result of Silicon material heterogeneity and effects that have been created throughout the manufacturing process.

In the next section we describe the proposed algorithm which is based on the use of PRNU noise.

4. Proposed Algorithm

Because there are different cameras with different features due to the use of sensors and other parameters, different models are derived from the images. Thus, this model could be used as a fingerprint of imaging devices to identify the source image. As mentioned before, our algorithm is based on PRNU pattern extraction and SVM classification. This algorithm has two parts: feature extraction and classification.

4.1 SVM Classification

Support Vector Machines (SVM) is a set of methods related to supervised learning that analyze the data and recognize patterns. Supervised learning is one of the machine learning methods to infer a function for supervised training data. To work with SVM, it is necessary to display each of the samples as a real numbers vector. Training data include a set of examples for training. We considered 30 images from each camera for training and tried to make various combinations of complexity or light in the image. In supervised learning, each sample has two components of inputs and outputs. Here the input component is a vector of qualities which is extracted from PRNU noise (which is different for each algorithm). Also we used PCA (principal component analysis) and SVD (single value decomposition) to reduce data size [11] and the most important data used in the models. Outputs are tags that define each of the four cameras. Supervised learning algorithm analyzes the training data and produces an inferred function that is called classifier. Inferred function forecasts the correct output value for any valid input component. It requires the Learning algorithm that is generated from the training data to cover the non-trained positions.

4.2 Features Extraction

The data used in this study consist of images of four cameras which are shown in Table 1 [14]. We considered 30 images for training and 100 images for testing per camera.

Table 1: Cameras that used for testing and training

ID	Model	Sensor	Image Size
C1	Canon EOs400D	CMOS	3888×2592
C2	Kodak EasyShare CX7530	CCD	2560×1920
C3	HP PhotoSmart E327	CCD	2560×1920
C4	Panasonic DMC-FZ20	CCD	3648×2738

PRNU noise is extracted by de-noising filter that is based on wavelet transform. The overall goal of de-noising filter is described in [2]. This filter derives the Gaussian noise with a known variance (which enters the filter as an input), based on this assumption, in the wavelet domain, image and noise are an increasing combination from a non-stationary Gaussian noise that has a certain variance. The tests show that the value of 5 for the given variance has the best efficiency everywhere. We obtain the residual noise from the image by removing the de-noised image from the original image. (Equation 1)

$$\text{Residual Noise} = I - I_{denoised} \qquad (1)$$

Here Idenoised is obtained with wavelet de-noise filter ([2]). Thus we obtain the high frequency components of the image that have been removed in the de-noised image as the image pattern noise. It is necessary to explain that the complexity and edges of the image influence the obtained pattern. You can see the result of implementing this method in PRNU noise extraction from a test image in Figure 1. In this method, PRNU is a matrix with image dimensions.

Fig 1: (left) original image, (right) PRNU noise pattern that includes high frequency components of the image.

In the most methods, the method of averaging the extracted noise pattern is used to obtain the camera noise model. This averaging is done for all images that were taken from a flat surface. Then, the camera type is detected using the correlation number of image noise model and camera noise model in cases such as [4,7] it has been tried to improve the extraction model.

The implementation results based on correlation can be observed in Table 2. In this method, vectors are the numbers related to the correlation rate of each image with the corresponding camera noise model in each color channel.

Table 2: Results of implementing algorithms based on averaging and correlation

	Train Accuracy (30 images)	Test Accuracy (100 images)
C1	84.17%	78.50%
C2	87.50%	84.25%
C3	78.33%	77.75%
C4	97.50%	95.50%
Average	86.88%	84%

Filtering process affects the pixel values around the edges of the image. So if the image has a complicated structure, its detection accuracy will be affected.

To solve this problem, we will propose an approach that is based on wavelet decomposition. Discrete Wavelet Transform (DWT) ([10]) divides the image into four sub-bands LL, HL, LH and HH (Figure 2).

We ignore the coefficients of HL, LH and HH that include vertical, horizontal and diagonal edges, then use The LL that represent the image approximate version where the edges have been trimmed. Furthermore, with this technique, we can reduce the size of image matrix and improve the efficiency PRNU noise extraction and vectors classification. Considering all the above issues, we use the LL part of wavelet transform and extract PRNU.

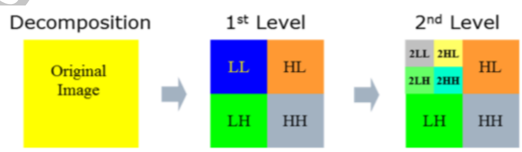

Figure 2: Bands of wavelet transform to the level 2

The purpose of using wavelet transform is to reduce the effects of edges. In Figure 3 the PRNU noise of original image and PRNU noise of LL part in wavelet transform in are compared. As you can see, the edges in the pattern obtained from the LL are trimmed, and the matrix size is reduced. However, this model can be used for SVM classification.

Steps that are used in the algorithm for each image to classify the input vectors are described below:

1. We calculate the wavelet transform of the image in the LL. (using Equation1)
2. We extract the Residual noise from the LL.
3. We use SVD or PCA to reduce the data size.
4. We consider a Vector obtained in the previous section as the input of SVM machines.

You can see the results for Level 1, 2 and 3 of wavelet transform in Table 3.

In this regard, dimensions of image become smaller 4l times in which 1 is equal to wavelet transform level. When we extract the residual noise from LL part of wavelet transform of the image in level 1, we have a matrix with quadrant of the image size, when we use SVD/PCA we reduce the dimension of this and has a vector (singular values in SVD and variances in PCA), Then we use 1000 features to classify. By a similar procedure for levels 2 and 3 of the wavelet transform, the number of the features is

500 and 200 to classify. So, we use 30 vectors that are extracted from 30 images for training SVM, then test the classifier with 100 vectors of test images.

By data reduction, we reduced arithmetic operation and increased detection rate significantly.

As you can see in the results, although the efficiency of this algorithm is good, the detection accuracy has also improved.

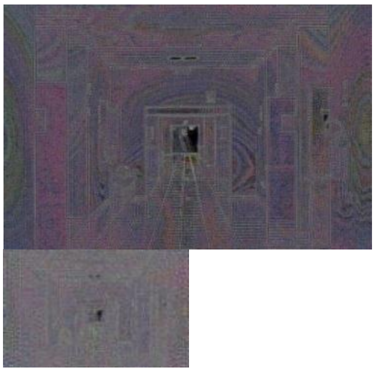

Figure 3: (Top) PRNU of original image, (bottom) PRNU of the LL in wavelet transform, edges are faded out and the image size is reduced.

5. Summary and Conclusions

In this paper, an algorithm is proposed for digital camera identification. The previous methods used the averaging of noise pattern to reduce the effects of image complexity on the noise model. This method is very time consuming and requires the purchase of a larger database containing images of a smooth surface for averaging. According to the results, the numbers obtained from correlation are not a suitable option for SVM classification. In cases such as [4], which some ameliorative are used for the noise model, the average accuracy of 80.8% has been achieved. In the proposed method, to reduce the complexity and edges of image and improve the noise model, the LL part of wavelet transform is used. It is clear that if the level is higher, the speed will increase due to the image size reduction but the algorithm accuracy will decrease. The results indicate that the PRNU extraction from the LL part of wavelet transform will give the best results in level 1.

Table 3: Results of using wavelet transform to fade out the edges of the image noise pattern

	Train Accuracy(30 images)						Test Accuracy(100 images)					
DWT Level	1		2		3		1		2		3	
Data Reduction	SVD	PCA	SVD	PCA	SVD	PCA	SVD	PCA	SVD	PCA	SVD	PCA
C1	99.17%	98.33	100%	99.2%	100%	98.3%	96%	91.75	97.5%	96.8%	96%	92%
C2	91.67%	92.5%	88.3%	92.5%	87.5%	90%	85.75%	81.25	83.8%	88.3%	79%	85.5%
C3	95.83%	96.67%	95.8%	95%	93.3%	93.3%	92.25%	92.75%	81.3%	80.3%	83%	86%
C4	98.33%	99.17%	100%	100%	100%	100%	92.5%	94%	97.3%	94%	97.7%	95%
Average	96.25%	96.67%	96.03%	96.68%	95.20%	95.40%	91.63%	89.94%	89.94%	89.85%	88.93%	89.63%

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