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Approaches for Camera Source Identification: A Review

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Abstract: ***Identifying the characteristics and the originality of the any digital device has become more important in today's digital world using digital forensics. This survey paper studies the recent developments in the field of image source identification. Proposed methods in the literature are divided into five broad areas based on source identification using Metadata (Exif), Image Features, CFA and Demos icing Artifacts, Lens Distortions and Wavelet Transforms. The methods and algorithm of the proposed approaches in each category is described in detail to use accurate technique in source camera identification.***

1. Introduction

Source identification using image examines the design of various techniques to extract and identifies the features of digital data acquisition device (e.g., digital camera and smart-phone) used in the acquisition of an image. These techniques are expected to give two major outcomes. The first is the class (model) properties of the source device, and the second is the individual source characteristics. The accuracy of image source identification techniques relies on the assumption that all images captured by an device will gives certain characteristics that are robust to the acquisition devices because of their (proprietary) image formation components and the image formation in that device, regardless of the content of the image. Image acquisition devices generally embed the device related information like date and time, type, model and compression details, in the image header, e.g., EXIF header. However, since all the encoded information about device is easily removed from image therefore can not be used for forensic purpose.

1.1. Image Acquisition in Digital Cameras

Image source identification system requires an understanding of the operation of image acquisition devices. The sequence of stages and general component structure of image construction pipeline remains same for almost all digital cameras. Most of the information is kept as basic information of each manufacture.

Consumer level digital cameras consist of a lens system, sampling filters, color filter array, imaging sensor and a digital image processor [1]. The lens system is essentially composed of a lens and the mechanisms to control exposure, focusing, and image stabilization to collect and control the light from the scene. After the light enters the camera through the lens, it goes through a combination of filters that includes at least the infra-red and anti-aliasing filters to ensure maximum visible quality. The light is then focused onto imaging sensor, an array of rows of columns of light-sensing elements called pixels. Digital cameras deploy charge-coupled device (CCD) or complimentary metal-oxide semiconductor (CMOS) type of imaging sensors. Each light sensing element of sensor array integrates the incident light over the whole spectrum and obtains an electric signal representation of the scenery. Since each imaging sensor element is essentially monochromatic, capturing color images requires separate sensors for each color component. However, due to cost considerations, in most digital cameras, only a single sensor is used along with a color filter array (CFA). The CFA arranges pixels in a pattern so that each element has a different spectral filter. Hence, each element only senses one band of wavelength, and the raw image collected from the imaging sensor is a mosaic of different colors and varying intensity values. The CFA patterns are most generally comprised of red-green-blue (RGB) and cyan-magenta-yellow (CMY) color components. The measured color values are passed to a digital image processor which performs a number of operations to produce a visually pleasing image. As each sub-partition of pixels only provide information about a number of color component values, the missing color values for each pixel need to be obtained through a demosaicing operation. This is followed by other forms of processing like white point correction, image sharpening, aperture correction, gamma correction and compression. Although the operations and stages explained here are standard stages in a digital camera pipeline, the exact processing detail in each stage varies from one manufacturer to the other, and even in different camera models manufactured by the same company.

2. TECHNIQUES FOR CAMERA IDENTIFICATION

The various techniques and features that are used to classify camera-models are given based on the differences in processing elements and the technologies. The deficiency of this methodology, in general, many model manufactures use components by from particular, therefore processing pipeline remain the same or very similar among different models of a brand. Hence, reliable identification of a source camera-model depends on classification of various model dependent characteristics as explains below.

2.1. Metadata

These is simple technique in which information about image is encoded in Image header when image acquisition takes place. It is easy to modify the header and change encoded information by third party. Nevertheless, once it is proven that there is no external modification with image metadata, analyzing the large amount of metadata can greatly help the forensic analyst. There are a huge amount of papers referencing the different types of metadata in pictures for search and classification purposes [2, 3, 4]. As stated before, these kinds of techniques, though simplest, depend on the metadata the maker may introduce. In fact, the most followed specification to identify the source of the camera, Exif [5], has two specific tags: “Make”' and “Model”, unfortunately filling data in those tags is not mandatory.

2.2. Image Features

Tsai et al in [6] proposed approach methods to determine source camera or mobile phone with camera. They used a set of image features to find out about the characteristics of the camera. The features include color features, quality Features and Image Characteristics of frequency domain. They adopt the Wavelet de-noising technique for calculating wavelet domain statistics and adding the SVM optimal parameter, then search step to enhance the identification rate of their previous work. The results obtained over four cameras models from two different camera brands yielded average accuracies close to 92%. McKay et al in [7] extends Image Source Identification to device types such as cell phones cameras, digital cameras, scanners and computer-graphics. To obtain this, they should find sources of variation among different types of camera devices and between different models of a device. This can be done using the dissimilarities in the image acquisition process of the imaging devices to develop two groups of characteristics, namely color interpolation coefficients and the noise properties. They can also use these features to obtain a correct identification. Five different models of cell phone is used in their work of experiment, five models of digital cameras and four scanner models to identify the source type. The results from their experiment gives accuracy of 93.75%. In their analysis of the identifying device brand/model of cell phone, obtained accuracy close to 97.7% for five models.

Jiang et al in [8] point out the fact that different patterns of sensor noise have been used for source identification successfully. When images obtained are processed using some common image processing operation, e.g., scaling, cropping and compressing then technique introduce some defect and results in poor source camera identification. The modification in image destroy the properties in image that used for source camera identification using image and generates problem in identification and classification.

2.3 CFA and Demosaicing

The choice of CFA and the specifics of the demosaicing algorithm are some of the most important differences among different digital camera-models. In digital cameras with single imaging sensors, the use of demosaicing algorithms is crucial for accurate rendering of high spatial frequency image details, and it uniquely affects the edge and color quality of an image. Essentially, demosaicing is a form of interpolation which in effect generates a specific type of inter-dependency (correlations) between color values of individual pixels of images. The specific form of these correlation can be identified and extracted from the images to fingerprint different demosaicing algorithms and to determine the source camera-model of an image. Brayman et al in [1], shows their different techniques to detect, identify and classify traces of demosaicing operation. They rely on two methods: The first method is based on the use of Expectation-Maximization algorithm which determines the correlation of each pixel value of image to its neighbours; the second method is based on analyzing inter-pixel differences.

The accuracy of identifying the source of an image from eight and ten camera-models and 150-170 camera devices is observed as 88% and 84.8%, respectively, using images taken under automatic settings and at highest compression quality levels.

In [9], Çeliktutan et al use a set of Binary similarity measures, which are the features used for measuring the correlation between the bit-planes of an image. The assumption taken into consideration is that trademarked CFA interpolation algorithm left correlation footprint across adjacent bit-planes of an image that can be represented by these measures. Image classification of images is done by 108 binary similarity measures. The results of experiment in this paper has accuracy is only 62% for 9 cameras collecting 200 images from each one of the maximum resolution, size of 640x480 pixels.

2.4 Use of Sensor Imperfection

Geradts et al [11] shows rhetorical characteristics of CCD but it does not give satisfied results. This approach includes pixel traps, cluster defects, point defects, hot points, dead pixel, pixel traps and cluster defects. The result shows that different device has different sensor patterns. Nevertheless, it also noted that the amount of defects in the pixels for a camera varies between pictures and differ greatly relies on the content of the image. It was also revealed that the number of defects varied at different temperatures. Finally, it is shown that not all cameras have that problem and some camera has mechanism to remove sensor noise from image.

In [12] Luka et al propose a technique based on the non-uniformity of the pixels (PRNU Pixel Response Non Uniformity), PRNU is a defect in image acquisition sensor, which provides characteristics of the sensors and therefore the camera. The result for different size images and cropped images is not up to the mark [13].

Floris Gisolf et al [17] propose a simplified total variation based noise removal algorithm for maximize the speed of PRNU extraction without losing accuracy as compared to wavelet based denoising. The result show that extraction is about 3.5 times faster with propose algorithm as compared to wavelet based denoising.

2.5 Wavelet Transform

Wang et al [18] Describe an approach to source camera identification extracting and classifying wavelet statistic features, this method is mainly composed of three phases: Wavelet Features Extraction, Wavelet Features Selection, and Wavelet Feature Classification. Outstanding features of wavelets domain are extracted integrating the statistical model for natural digital image from the wavelet coefficients contains 216 higher-order wavelet features and 135 wavelet coefficient co-occurrence statistics. Being considered as the most significant in the identification process, features from the wavelet domain are preferred over spatial features (image color and Image Quality Metrics IQM) and Colour Filter Array (CFA). Analogously to the foregoing method, Four-scale wavelet decomposition is employed based on Separable Quadrate Mirror Filters (QMFs) to split the frequency space, the same four statistics (mean, variance, skewness and kurtosis) and the linear prediction errors are extracted. Under the same conditions as in their prior experiments they succeeded in distinguishing different models of the same camera brand and besides, they increased their past accuracy average to a 98%. This improvement might be due to the consideration of texture features, minimizing the negative effects found in the classifier training when using multiple resolutions in images of the same model and brand.

3. IDENTIFIED FUTURE SCOPE

Future work includes source camera identification using videos. Retrieving and classification of images and videos by various source camera identification approaches can be open research work.

4. CONCLUSION

In this paper we have studied different existing techniques for solving the image source identification problem. We categorized them into five primary groups according to the processing strategy that they apply: Metadata, Image Features, CFA and Demosaicing Artefacts, Use of Sensor Imperfection and Wavelet Transforms. The main idea of the proposed approaches in each category is described in detail, and reported results are given to evaluate the potential of the methods.

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