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Forgery Detection using Noise Inconsistency: A Review

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***ABSTRACT*: The effects of digital forgeries and image manipulations may not be seen by human vision but they alter the statistics of the image. Passive blind methods are designed to detect such statistical variations in the image. Hence they do not need the addition of the digital signatures or digital watermarks for detecting image authenticity. In this paper, the methods of forgery detection using noise inconsistencies in the images are discussed because noise is the most commonly used tool to hide the traces of the tampering. Additional noise has a negative impact on the originality of the images. Usually the noise in the image is uniform throughout but the addition of locally random noise causes inconsistencies in the noise variance of the image. The inconsistency in the noise may turn out to be an effective way to detect the tampered regions. The discussion includes review of methods used for detecting noise inconsistencies in the image along with their advantages and limitations.**

Keywords: Image forgery, Noise inconsistency, Tampering detection, Image manipulation, Noise level estimation, Noise variance, Detection of Image Fakery, Image authenticity.

I. INTRODUCTION

Digital images are being used in our daily lives. Digital imaging has demonstrated its worth in a various fields like education, medicine, military, media, scientific purpose, glamour, forensics, industrial purpose etc. So the integrity of images used in these fields is paramount. With the advent of the internet, the image manipulations have become very easy as there are various photo editing tools available.

Various techniques have been developed for checking the authenticity of the images. These are categorized as active [1-2] and passive methods [3-7] of forgery detection. Active methods need prior knowledge of the image, for e.g. embedding watermarks into the image or the use of digital signatures at the time of image creation. This is why their applications are limited. To overcome the drawbacks of active approaches, passive methods were developed.

Passive methods operate in the absence of digital watermark or signatures. Effects of digital forgeries may not be seen by our visual system but they surely alter the statistics or consistency of the image. They are categorized as shown in Fig.1. There exist various literature on passive or blind methods which are mentioned in the references [3-7]. They are mainly categorized as six main types: (1) In Pixel-Based Technique, as we know the pixels are the basic building blocks of an image, so the total emphasis is on the pixels. Various techniques are further available that work on pixels like cloning, resampling, splicing and statistical approaches. (2) Another category is Format-Based techniques. These are used when lossy compression is done on the images. They are further of three types: JPEG Quantisation, Doubly JPEG and JPEG blocking. Camera based techniques. (3) Camera Based technique that exploit the artefacts introduced by the camera lens, sensor or on-chip processing. Various factors are taken into account like Colour aberration, colour filter array, and sensor noise and camera response. (4) Physics based techniques model a three dimensional interaction between the objects, camera and the sensor and detect anomalies. (5) Geometric-based techniques are used to make measurements of objects and their positions relative to the camera. Usually the PCA approach is used in this technique.

All these techniques are successful only when there is certain level of consistency of noise present in the image. Noise inconsistency in the image degrades the performance of all the passive methods of forgery detection.

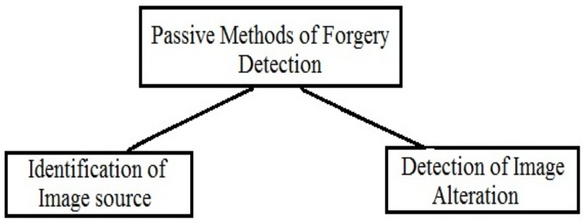

Fig. 1 Types of Passive Methods

Noise is the most commonly used tool to hide the traces of the tampering process. For example, a block of certain region is copied and pasted to the same image (e.g. to hide some object, person etc.) in order to forge the image. To conceal the edges of the block, certain noise is added. By doing so, the locally random noise thus added may cause inconsistencies in the image's noise. There can be some other reasons for such variations or inconsistencies such as colour, lighting variations or the texture. Usually the original image has uniform noise all over the image. So detecting the noise inconsistencies in the image may signify the tampered regions. The next section summarizes the previous work done based on noise and noise features. The important properties of each method are discussed and their drawbacks are also discussed.

II. General Method Used For Noise Level Estimation

There is very limited literature available on noise estimation. Multiple samples of images or a single image can be used for noise estimation. Additive white Gaussian noise is assumed to be present in most images. Noise level estimation is generally divided into three basic categories. They are: Block-Based noise estimation, Gradient-Based Noise estimation and Smoothing Based noise estimation. Noise estimation is done using two approaches viz. Principal component analysis (PCA) and Discrete cosine transform (DCT). All the detection methods based on noise inconsistency are highly dependent on the accuracy of the noise level estimate. Noise level estimations are used in image de-noising, compression, segmentation etc. The general approaches used by various noise level estimation algorithms have some common steps:

A. Signal separation from the noise.

1) Pre-classification of homogeneous areas. Images contain homogeneous areas which are most appropriate for estimation of noise variance, because the variance of the image with noise is equal to the noise variance there.

2) Filtering. After pre-classification of homogeneous areas, image filtering is performed i.e. the convolution of processed image with a high-pass filter like Laplacian filter is done; or the difference between the image under processing and the response of a low-pass filter is computed. The result of the filtering process contains the noise as well as object edges. Edge detectors are used to recognize and remove the object edges. The final result contains only the noise and hence the noise variance can be directly estimated.

3) Wavelet transform. Level 1 decomposition is assumed to be the finest decomposition of the wavelet transform of an image. The wavelet coefficients of that decomposition level (subband HH_1) correspond only to the noise is the simplest assumption. This assumption leads to significant overestimates, because these wavelet coefficients are also affected by image structure as well. The assumption is made that the noise is caused by the wavelet coefficients which have the value smaller than some preset threshold. The threshold is calculated by some iterative procedure.

B. Analysis of the local variance estimate distribution.

The separation results of the signal and noise are often not perfect, therefore the outliers are present in the local distribution variance estimation which is computed for image blocks. Therefore, statistical methods which are not sensitive to outliers are applied in order to get the final noise variance estimate. There are several approaches which have been proposed like the median of local estimates, the mode of local estimates, and the average of several smallest local estimates. The noise level estimation is done usually using two approaches: one is Discrete Cosine Transform (DCT) of image blocks and the other one is Principal component Analysis (PCA). In DCT approach, the image blocks concentrates image structures in low frequency transform coefficients, allowing noise variance estimation using high frequency coefficients; 3-Dimensional DCT of image block stacks [8] utilizes self-similarity of the image in order to separate the signal from the noise. Another method is principal component analysis (PCA) of image blocks, which has been already successfully utilized in various image processing tasks such as compression, de-noising, and quality assessment. There are various advantages of this method which include high computational efficiency; processing of images with textures, even if there exists no homogeneous areas; gives the same or improved accuracy compared with the state of the art.

III. Previous Work

There exist few blind methods based on noise properties of the images. Noise detection has been used for identification of the image source and fakery detection. These methods do not require a priori information about the image or the source camera that was used to take the image under consideration. Some significant work has been discussed in this paper.

Hongmei Gou et al., [9] introduced a technique for forgery detection and steganalysis on digital images using three sets of noise features. The de-noising algorithms were explored to get the estimation of image noise. The wavelet analysis and prediction errors of neighbourhood were used to obtain the second and third set of features respectively. A classifier was created with the help of these features to differentiate between the direct camera output and the tampered versions or the stego versions. This method fails to give the accurate extent and location of the altered region. Another drawback of this method is that only particular camera models were examined by the supervised learning method.

Another method of detecting forgery is by using noise variance estimation at image blocks to point out the suspicious regions. Popescu and Farid [10] proposed noise inconsistencies detection method which was based on estimation of noise variances of overlapping blocks in which the overall image is tiled into blocks. In this method, white Gaussian noise and non Gaussian uncorrupted image is assumed. Main drawback of this method is that the kurtosis of the original image is assumed to be known which is not true in practice.

Xunyu Pan [11] proposed a forgery detection method to locate image tampering regions based on clustering of image blocks with different noise variances. The image that is to be tested is segmented into blocks for initial noise estimation by the method given in [12]. For refining the noise estimation, the suspected image is further segmented into image blocks. Segmentation is also done for classification in phase two to get the final detection results. This method is based on the Kurtosis concentration property of the original/authentic image.

Jiayuan Fan [13] used an effective technique to find correlation between statistical image noise features and

Exchangeable Image File Format (EXIF) header features for detecting manipulation. Image manipulations like brightness and contrast enhancements can alter the noise features of the image. The authors observe the numerical differences between the original EXIF features and the corresponding EXIF features from the estimated noise features. That difference can serve as a great indicator to determine if the image is the original one that is taken from a camera source or it has gone through some manipulations. Again some specific camera models were examined by this method. Ahmer Emir Dirik and Nasir Memon [14] proposed a detection method which was applicable to various operations like splicing, retouching, recompression, resizing, blurring etc. But it did not target any specific operation.

B. Mahidian, S. Saic [15] introduced a method which was capable of dividing the investigated image into various homogenous segments according to noise level. It is obvious that the noise variance vary spatially as the image is altered. The method introduced was based on four main steps. Initially the noise variance values and the size and location of the segments are unknown. The white Gaussian noise is assumed to be present in the image. Wavelet analysis is considered the effective way for performing tasks related with image noise. One-level wavelet decomposition of the image under investigation is carried out. The diagonal details of the image of highest resolution are obtained from the sub-band. An operator is used to manually segment the image into portions. A region of interest (ROI) can be identified by using one of the forgery detection methods which are capable of localizing the tampering regions. After this step, block's noise variance is estimated by using the noise estimation technique. Various methods have been developed to get the noise level estimation. They are categorized as: Block based, smoothing based and gradient based. B. Mahdian and S. Saic used the wavelet component method which is a special case of gradient based method for estimation of noise level. In this method the gradient amplitudes are obtained by decomposition of wavelets.

Now the noise estimation of each block is estimated, then the image is divided into various homogenous sub-regions which are connected to each other. To achieve the homogeneity condition, the blocks are merged using merging technique [16-18]. It initializes with a single block and then combining similar neighbouring blocks. The output is in the form of a map which shows the regions with similar noise variance. This method is not capable of finding the tampered region when the noise degradation is very small. Human interpretation is also required as the authentic image may have some inconsistencies in noise. Another drawback is that the method was proposed for gray-level images. For RGB images, the method has to be implemented on each channel.

Y. Ke, Q. Zhang, [19] proposed a method in which the noise variance is estimated on HSV colour space. The image under consideration is converted into HSV (Hue Saturation Value) from RGB colour space. Image is then segmented to non-overlapping image blocks. The noise inconsistency of each block of the image is obtained with the help of a noise estimation technique (using Principle component analysis). The estimated noise variance is classified using unsupervised clustering algorithm (k-means). All the blocks are categorized in two clusters. HSV colour space is believed to be more natural than RGB colour system for human perception. There exist three variables viz. hue(H), saturation(S) and value(V). The saturation component is selected from the HSV colour space for further block segmentation. The segmented blocks are assumed to be smaller than the size of the tampered regions that are to be detected. The accuracy and efficiency of the noise estimation method depends on the size of the image blocks. The performance of noise estimation is evaluated by applying noise estimation algorithm using PCA on randomly selected blocks with varying sizes. In this paper, the block based noise estimation technique is used. This method is capable of processing the images with textures, even when there exist no homogenous areas. The area of the corrupted region is usually smaller than the original image counterparts. It can be applied to manually blurred images. This method can also detect the corrupted regions of blur operation with reasonable accuracy. To improve this method, it can be applied along with blurring inconsistency.

IV. CONCLUSIONS

As we know that it is difficult to find the marks of tampering in a digital image so it is necessary to know the efficient methods for the detection of these tampering. For forgery detection, the passive methods are used because they do not need any prior information about the image or any pre-processing on the image. The blind methods based on noise inconsistency are reviewed in this paper. Our goal was to provide a summary of all the methods with the advantages and the drawbacks of each method so that the researches can review the literature in a single paper for their further study (refer Table 1). Noise has been the most disturbing element for all forgery detection techniques. Even though all the methods that are discussed above are fully capable of detecting the forgery effectively but some of the methods are found to be image sensitive i.e. they require the images to be in a particular format or in a particular colour space. Thus, future research on detection of Image Tampering should focus on developing a false proof method that is independent of the image format.

TABLE I
VARIOUS METHODOLOGIES AND THEIR DRAWBACKS

Paper Title	**Author**	**Methodology Used**	**Drawbacks**
Noise Features for Image Tampering Detection and Steganalysis	H. Gou, A. Swaminathan and M. Wu [9]	Three sets of noise features were used in this method for steganalysis on digital images.	(1) This method fails to give the accurate extent and location of the altered region. 2) Only particular camera models were examined by the supervised learning method.
Statistical Tools for Digital Image Forensics	Popescu and Farid [10]	Noise inconsistencies detection method which was based on estimation of noise variances of overlapping blocks in which the overall image is tiled into blocks.	Main drawback of this method is that the kurtosis of the original image is assumed to be known which is not true in practice.
Exposing Image Forgery with Blind Noise Estimation	X. Pan, X. Zhang and S. Lyu [11]	Locates image tampering regions based on clustering of image blocks with different noise variances.	This method is based on the Kurtosis concentration property of the original/authentic image.
Estimating EXIF Parameters Based on Noise Features for Image Manipulation Detection	J. Fan, H. Cao and A. C. Kot [13]	Used an effective technique to find correlation between statistical image noise features and Exchangeable Image File Format (EXIF) header features for detecting manipulation.	Again some specific camera models were examined by this method.
Image Tamper Detection Based on Demosaicing Artefacts	D. A. Emir and N. Memon [14]	Forgery detection method which was applicable to various operations like splicing, retouching, recompression, resizing, blurring etc.	It did not target any specific operation
Using Noise Inconsistencies for Blind Image Forensics	B. Mahdian and S. Saic [18]	Divides the image under consideration into various homogenous segments according to noise level. It used the wavelet component method which is a special case of gradient based method for estimation of noise level.	Not capable of finding the tampered region when the noise degradation is very small. Human interpretation is also required as the authentic image may have some inconsistencies in noise. Another drawback is that the method was proposed for gray-level images. For RGB images, the method has to be implemented on each channel.
Detecting Image Forgery Based on Noise Estimation	Y. Ke, Q. Zhang, W. Min and S. Zhang [19]	The noise variance is estimated on HSV colour space.	To improve this method, it can be applied along with blurring inconsistency.

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