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# Multi-scale noise estimation for image splicing forgery detection ☆

Chi-Man Pun *, Bo Liu, Xiao-Chen Yuan

*Department of Computer and Information Science, University of Macau, Macau*

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ABSTRACT

Noise discrepancies in multiple scales are utilized as indicators for image splicing forgery detection in this paper. Specifically, the test image is initially segmented into superpixels of multiple scales. In each individual scale, noise level function, which reflects the relation between noise level and brightness of each segment, is computed. Those segments not constrained by the noise level function are regarded as suspicious regions. In the final step, pixels appears in suspicious regions of each scale, after necessary morphological processing, are marked as spliced region(s). The Optimal Parameter Combination Searching (OPCS) Algorithm is proposed to determine the optimal parameters during the process. Two datasets are created for training the optimal parameters and to evaluate the proposed scheme, respectively. The experimental results show that the proposed scheme is effective, especially for the multi-objects splicing. In addition, the proposed scheme is proven to be superior to the existing state-of-the-art method.



## 1. Introduction

Due to the wide availability of picture editing software, normal individual can manipulate the digital image quickly and easily. Therefore anyone can hardly tell if an image is original or fake when seen in the Internet. On most circumstances it does not matter, but in some special cases, it makes difference. A famous fake picture can affect public opinions and even worse a fake picture as an evidence in the court may lead to irreparable damage. Accordingly an effective and robust image forensic method is of great importance. However there are so many kinds of operations can be added to a digital image such as contrast enhancing [1], copy-move [2] and splicing [3], and a single algorithm to deal with various types of attacks is very challenging though there are some attempts [4]. In order to achieve better detection accuracy, in this paper, we will focus on a common operation, splicing, which refers one or more regions of a picture come(s) from the other pictures. This type of manipulation is widely seen in our daily lives, because these fake pictures often contains huge information which people will be interested in. Existing splicing forgery detection algorithms will be briefly reviewed in the following.

In order to make tampered pictures look real, some operations such as geometrical distortions and contrast altering of spliced area, will be applied to the image, and these manipulations can be detected as evidence of splicing forgery. Mahdian and Saic [5] analyzed statistical changes of signal by interpolation process which is involved with scaling, rotation and skewing of inserted regions. Wei et al. [6] extended Mahdian and Saic's work and their method can estimate the image rotation angles. However, the interpolation-related methods are vulnerable to low quality JPEG compressions and cannot locate very small spliced areas. Detection of contrast enhancement was proposed by Cao et al. [1], however, it is not robust to JPEG compressions as well.

Since JPEG format is widely used and composing two images together usually involve the operation of double JPEG compression, methods based on detecting double compression have been proposed. Farid [7] proposed the method to detect if the part of an image is firstly compressed at a lower quality. And algorithm proposed by Bianchi and Piva [8] was to deal with more scenarios, as first and second quantization table are different. And Valenzise et al. [9] proposed forward quantization noise in JPEG compression to deal with high-quality compressed images in forensics. These JPEG-based methods rely on comparatively strict hypothesis. And multi-compression is common but too complex to analyze. Most of these methods become ineffective when pictures are compressed more than two or three times. In addition, block artifact grids (BAG) caused by block processing during JPEG compression can be used in splicing detection [10]. Besides JPEG compression, contents of pictures also provide traces for forensics. Inconsistent of motion blur, which is produced by camera vibrations or insufficient shutter speed, provides evidence for detecting splicing forgery [11,12]. Illumination environment in pictures also present

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* Corresponding author.
*E-mail addresses:* cmpun@umac.mo (C.-M. Pun), yb57413@umac.mo (B. Liu), xiaochen_yuan@ieee.org (X.-C. Yuan).

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some consistency: directions of lights [13], shadows [14] and illumination colors [15] can be estimated and used as cues.

Apart from user's operations and image contents, the digital camera including optical lens will leave some information in the final picture and they can be used for exposing forgery. Modern digital camera uses Color Filter Array (CFA) overlaid on image sensor to catch RGB colors and utilizes demosaicing algorithm to reconstruct full color images. The local absence of demosaicing artifacts is regarded as tampering in [16]. Chromatic Aberration (CA), and produced by imperfect optical system, can be modeled and inconsistent CA across the image will be a forgery indicator [17]. The property that mapping input irradiance to output image intensity, called as Camera Response Function (CRF) can also be used in forgery detection [18]. The image is randomly segmented and CRF of each segment is estimated, and inconsistent across the image is regarded as splicing. But according to the experimental results, the accuracy of locating forged area is modest. Besides the fingerprints of image sensor, the characters of curtain lenses can also be used. Fu and Cao [19] studied the geometric distortions of wide angle lenses and objects without consistent distortion is detected as inserted regions. However, the work is limited to images captured with very wide angle lens since normal lenses shows little distortion which is hardly calculated. Besides CA and CRF, Photo Response Non-Uniformity (PRNU), which contributes to pattern noise in digital cameras [20,21], can also be formulated to identify a series of sensors. However it is very time-consuming and unpractical to compute PRNU for each camera model. Therefore many researchers investigated the noise patterns in the image to discriminate splicing forgery [22,23].

While most of the previous algorithms as stated above rely on specific and strict hypothesis, our goal is to detect more accuracy splicing forged regions without much assumptions. Considering that noise is widely existed in natural pictures taken by digital camera, and each picture contains certain level and type of noise, which is produced during the whole process when photons coming into the sensor until the camera output the picture [24,25], in this paper, we propose to detect the forgery based on noise estimation. To estimate the noise level of a given picture, the phenomenon of kurtosis concentration [26,27] which kurtosis value of natural images in band-pass filtered domains concentrates to a constant value helps estimate noise variance [28]. However this method is based on the assumption that the intrinsic noise is similar across the original image. The truth is the noise level is not similar within the image, and it is always affected by brightness and textures [29]. And the omission of these trivial but important noise difference has bad impact on the detection result. Noise level function is thus proposed to deal with the noise fluctuations [30]. Since the brightness will influence the noise level in the digital image, and the noise level function can describe the relations of the brightness and noise level, inconsistent with noise level function will be considered as forged.

The paper is organized as follows. In Section 2, the multi-scale estimation method for detecting splicing forgery is introduced. In Section 3, a training dataset is used to find optimal parameters for algorithm termination and a forgery dataset is created to evaluate the proposed method and lots of experiments are conducted to present the performance of the proposed scheme. Besides, comparisons with existing state-of-the-art method are demonstrated to show the superiority of the proposed scheme. Section 4 concludes the paper and states the future work.

## 2. Multi-scale noise estimation for splicing detection

The existing noise estimation methods are not always reliable and accurate in dealing with small image segments [31,32], since local noise estimation is affected by image segmentation and content. And therefore inaccurate noise estimation influences the following steps of forgery detection. Accordingly we propose multi-scale segmentation scheme to compensate such effects. Instead of segmenting the image with fixed initial size [33], in our method we propose to segment the host image in multiple scales, where a minimum initial size is defined and the initial sizes for the multiple scales are accordingly increased progressively at regular intervals. In this way the noise estimator will be applied into all scales respectively to estimate the noises and finally the algorithm is designed to automatically composite results from all scales together. Apart from more accurate noise estimation results, the multi-scale segmentation plays an important role in detecting multi-objects forgery and especially when the objects are of various sizes. Fig. 1 demonstrates the better detection results of our algorithm comparing with the existing state-of-the-art method proposed by Lyu et al. [33], where the noise estimation method was proposed in single scale to detect the splicing forgeries. In Fig. 1, the 1st row shows the example where multiple objects of various sizes are pasted into the host image (a1) to generate the forged image, as shown in (a2); and the 2nd row shows another example where a pretty large object is pasted into the host image (b1) to form the forged image, as shown in (b2). (a3) and (b3) in the 3rd column show the detected results of Lyu's method, where the *precision* and *recall* rates are evaluated: *precision* = *77.45%*, *recall* = *18.99%* and (a4) and (b4) in the 4th column show the detected results of the proposed scheme: *precision* = *81.14%*, *recall* = *94.84%*. It can be easily seen from these two typical examples that the proposed scheme outperforms Lyu's method [33] a lot in both *precision* and *recall*.

Fig. 2 presents the overview of the proposed method. First, the multi-scale image segmentation algorithm is proposed to segment the input image. Given the host image as shown in (a), the multi-scale segmented images are then generated using the multi-scale image segmentation algorithm, as shown in (b). Next, in each scale, the noise level is estimated to build the noise level function, with which, outliers, the segments with comparatively higher or lower noise level, are detected and indicated as suspicious forged area. Afterwards, in each scale, the outliers map which has recorded all outlier segments is updated by combining previously constructed outliers map, and only regions appears in both maps are remained as forged area. Finally, a termination criteria is defined by judging the stability of the outliers maps or whether the iteration times has reached the preset maximum times $i_{\max}$. The following Sections 2.1,2.2 and 2.3 will elaborate, respectively, the multi-scale image segmentation algorithm, the outlier detection using noise level function, and termination condition, especially the method to measure the stability of outliers map.

### 2.1. Multi-scale image segmentation

This paper introduces a novel multi-scale image segmentation method to segment an image. The traditional image segmentation algorithms usually segment a host image into small clusters with a given initial size. In the proposed method, the multi-scale segmentation method is proposed to segment a host image into successive scales, and the segmentation result in each scale corresponds to that of traditional image segment algorithms, with independent and different initial sizes. During the segmentation, the Simple Linear Iterative Clustering (SLIC) algorithm is applied to the input image to segment it in multiple scales. The reason why we adopt multi-scale segmentation is that the proposed algorithm is designed to detect as many types of forgery as possible. Specifically, the multi-scale image segmentation method can detect forged regions of various size. It is fairly difficult to detect and locate