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An efficient weak sharpening detection method for image forensics☆

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ABSTRACT

In recent years, image sharpening detection has become one of the main topics in the field of image forensics. It is, however, still a challenge to detect the images sharpened with weak sharpening strength. To address this challenge, we propose an efficient method for image sharpening detection. In the proposed method, a ternary coding strategy with adaptive threshold is introduced to reveal the overshoot artifacts caused by weak sharpening. Extensive experiments are conducted to illustrate the superiority of the proposed method. The experimental results show that the proposed method can achieve a considerable improvement in sharpening detection, especially for slightly sharpened images.

1. Introduction

Image forensics is a research field aiming to verify the origin and authenticity of digital images [1–6]. In the last decade, it has become more and more popular with the explosive development of image editing techniques. Image sharpening detection is one of the main topics in image forensics, and it has multiple application scenarios: first, image sharpening is one of the basic tools of image retouching [7], so image retouching could be exposed and measured by image sharpening detection; second, image sharpening has been widely applied to digital cameras [1], and different camera companies usually adopt different image sharpening techniques. Hence, the camera brand could be identified by detecting which sharpening technique is applied in the capture of images; third, image splicing is one of the main ways of making forged images [8]. We consider a scenario that a forged image is spliced by two source images, one of which is sharpened, the other not. In this scenario, the spliced region could be localized by detecting sharpening in the forged image in a block-by-block manner.

Image sharpening highlights the desired details of digital images. After sharpening, the contrast of image edges is usually increased. Properly sharpened images without distortions often provide better quality. The most popular sharpening method is unsharp mask (USM) [9], which is utilized in many kinds of image processing software such as Photoshop. Despite its confusing name, USM actually creates a sharp mask by deducting the low frequency components from the original image and then combines this mask with the original image to produce a sharpened image. There are also other sharpening techniques such as Laplacian sharpening and bilateral sharpening.

In order to improve edge contrast, dark pixels become darker and bright pixels become brighter along image edges. This phenomenon is named as overshoot artifact. The overshoot artifact can be regarded as a unique feature of image sharpening. Hence, it often serves as a clue for sharpening detection. The sharpening methods with overshoot artifact control [10,11] have been introduced to avoid the occurrence of overshoot artifact. These sharpening methods offer an option of strong sharpening with overshoot artifact under control to provide better image quality. Overshoot artifact control is meant to reduce the effect of overshoot artifact, which may bring more difficulty for sharpening detection.

Image sharpening detection was first studied by Cao et al. [12]. In [12], the authors proposed to detect image sharpening by analyzing histogram aberration and measuring the strength of overshoot artifact. But, overshoot artifact was exploited only as a supplement. So, this method failed in sharpening detection for the images with narrow pixel value histogram. Later, Cao et al. [13] realized that overshoot artifact is a powerful feature in sharpening detection, and it is effective and sufficient for sharpening detection by just analyzing overshoot artifact. Hence, in [13], the deficiencies of [12] are surmounted by measuring the strength of overshoot artifact. Basically, the method of [13] needs to set a proper threshold, and then makes decision by comparing the threshold with the overshoot artifact strength of images. Comparing with [12], the detection accuracy can be apparently increased if the threshold is properly set. In [14], local binary pattern (LBP) was introduced to sharpening detection. LBP was first proposed in [15], and

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has been proved to be a simple but outstanding texture analysis tool in many applications such as camera identification [16], computer graphic (CG) and photo graphic (PG) classification [17], texture classification [18] and steganalysis [19]. In [14], the authors applied LBP in edge pixels to extract features for sharpening detection. The experimental results indicate that this method surpasses the detection ability of [13]. The LBP is a universal texture analysis tool. However, it is believed that the sharpening detection performance will be boosted if a specific method could be designed for analyzing overshoot artifact. Based on this consideration, edge perpendicular binary coding (EPBC) was proposed in [20]. EPBC has been shown to be a more advanced method comparing with the above mentioned detection methods.

However, most of these existing methods fail to detect weak sharpening. When the image is slightly sharpened, the effect of overshoot artifact is inconspicuous. This prevents the detection algorithms to be functional against slightly sharpened images. In most cases, it requires images to be sharpened with proper strength. Because strong sharpening brings out distortions and noises which are not acceptable by human eyes, the sharpening intensity is always controlled to be medium or light. This requires the sharpening detection method to be feasible under low sharpening intensity. However, current state of the art cannot identify and hence deal with slightly sharpened images. In order to solve this problem, we propose a new detection method called edge perpendicular ternary coding (EPTC). Extensive experiments have been conducted to validate the efficiency of the proposed method. Note that a preliminary version of this work was presented at a conference [21]. In this paper, the work is extended by adding more literature review, methodological description, and discussions.

The rest of this paper is organized as follows. Image sharpening is briefly introduced in Section 2. In Section 3, the proposed detection method is presented and described in detail. Experimental results are reported and discussed in Section 4. Finally, we conclude our work in Section 5.

2. Image sharpening

2.1. USM sharpening

USM sharpening is the most representative sharpening method, which can be performed by nearly every image editing software. It is firstly applied in photography before widely applied as digital image sharpening technique. Details of images can be enhanced by increasing small scale acutance with USM.

In order to sharpen image I, USM sharpening needs to create an unsharp mask M at first. This can be performed by passing image I through a high-pass filter H, that is,

$$M = I \otimes H, \tag{1}$$

where $\otimes$ denotes the convolution operator. This mask can also be considered as an image residual carrying only high frequency components. All the low frequency components are simply eliminated.

The mask is scaled with a sharpening strength before being combined with original image. Then, the sharpened image is generated by

$$I' = I + \lambda M, \tag{2}$$

where λ denotes the sharpening strength which controls the magnitude of overshoot artifact during sharpening. This strategy makes the sharpening intensity flexible to provide images with desired quality. Since only the high frequency components are preserved in the mask, after adding it back to the original image, only the high frequency components are amplified. Meanwhile, areas with low frequency remain unchanged after sharpening.

In order to decrease noises during sharpening, in PhotoShop, the mask is produced in a different way. Rather than directly processing images with high-pass filter, PhotoShop employs Gaussian low-pass filter to preserve high frequency components. This is achieved by

$$M = I - I \otimes G_\sigma, \tag{3}$$

where G_σ denotes Gaussian low-pass filter with variance σ. σ serves as the sharpening radius to decide the size of area to be enhanced. It makes the sharpening range controllable by performing sharpening on edges with specific frequency.

2.2. Overshoot artifact

Essentially, sharpening amplifies high frequency components in image. Besides noise, areas with high frequency components are mostly recognized as image edges. Hence, the contrast of edges can be enhanced by amplifying high frequency components. In luminance value domain, the gradients of edges are increased after sharpening. Because the large difference of luminance values on the edges, the edge pixels have great magnitude gains after sharpening. At the meanwhile, other pixels which locate in low frequency areas can generally maintain their pixel values in sharpened images. These factors eventually cause the appearance of overshoot artifact on edge pixels.

The overshoot artifact O reflects the magnitude gain of edge pixels. The magnitude can be either positive or negative, which is related to the position of the pixel on edge. If the luminance value of an edge pixel is denoted as P_i, then after sharpening, its value changes to

$$P_s = P_i + O. \tag{4}$$

Because overshoot artifact is frequently found on edges in sharpened images, it can be introduced as a unique characteristic of sharpening. If the overshoot artifact appears with high probability on edges, it can be utilized as evidence of sharpening in forensics.

In most common cases, sharpening strength is set in a low level to perform proper sharpening for human eyes. If the sharpening strength is extremely intense, the magnitude gain for non-edge area can be also amplified to a significant level. Thus, numerous overshoot artifacts can be found all over the images. This will cause serious distortions in sharpened images.

2.3. Adaptive directional sharpening with overshoot control (ADSOC) [10]

Sharpening can offer images with a clear view of the details, but it also brings the side effect induced by overshoot artifact, which may cause distortions and noises in certain cases. After sharpening, the value difference of two pixels on the edge is amplified to increase contrast. For this reason, it is inevitable to meet overshoot artifact on edges. However, if overshoot artifact can be limited, then we can obtain better quality images without tolerating much distortions and noises. Hence, sharpening with overshoot artifact control was proposed to satisfy this demand. ADSOC is a typical method in the category. With this method, it is able to perform a strong sharpening on image area with more details while preserving the pixel values of regions with low frequency. It mainly operates on edge pixels to limit the intensity of overshoot artifact regardless of sharpening strength. It can be also observed in Fig. 1 that the overshoot artifact generated via ADSOC is extremely low by comparing with ordinary sharpening methods. When applying this scheme, if the edge pixels exceed the limit range, the gain of sharpening will be reduced with a rule as follows:

$$P_s = \begin{cases} R_{max} + \alpha(P_i + O - R_{max}) & P_i + O > R_{max} \\ P_i + O & R_{max} \geqslant P_i + O \geqslant R_{min}, \\ R_{min} - \alpha(R_{min} - P_i - O) & P_i + O < R_{min}, \end{cases} \tag{5}$$

where α is an overshoot control parameter ranged from 0 to 1, and R denotes the range for overshoot artifact which is adjustable manually. The exceeded overshoot artifact will be shrunk in a desired proportion. The limited overshoot artifact definitely causes more difficulty for sharpening detection, especially for Cao et al.'s method. But, it is still impossible to completely erase overshoot artifact during sharpening. Methods based on texture analysis are assumed to be well suited for