Detection of Block Artifacts for Digital Forensic Analysis

Chang-Tsun Li

Department of Computer Science
University of Warwick
Coventry CV4 7AL, UK
ctli@dcs.warwick.ac.uk

Abstract. Although the metadata, such as the header, of a piece of media carries useful information, the metadata may be tampered with for various purposes. It is therefore desirable in the context of forensic analysis that investigators are able to infer properties and information about a piece of media directly from its content without any reference to the metadata. The block size of the block operations that a piece of media has undergone can provide useful clue about the trustworthiness of the metadata and in turn reveals the integrity of the media. In this work, we proposed a novel block artifact detection method for inferring the block size of block-wise operations, such as JPEG compression, that has been applied to the media under investigation. Based on the assumption that block operation create disparities across block boundaries and those boundaries form straight lines, our method exploits the fact that intra-block variance tend to be less than inter-block variance and if most of the pixels along the same vertical line or horizontal line exhibit this relationship then the straight line is believed to be the block boundary.

Keywords: Digital forensics, block detection, computational forensics, block artifacts detection.

1 Introduction

Digital watermarking [2], as a means for authenticating multimedia contents and copyright protection, has attracted enormous efforts in the past decade. Albeit digital watermarking's promising potential, to make it work, a digital watermark has to be embedded into the host media in advance. However, the majority of digital media already produced and to be produced in the near future are not watermarked. This situation poses pressing forensic and security issues as the wide availability and the ease of use of multimedia processing software provide potential offenders convenient avenues for manipulating digital contents for malicious purposes. In response to the needs for analyzing multimedia contents in the context of digital forensics, methods of *non-intrusive forensic analysis* (sometimes called *passive forensic analysis*) of multimedia contents have been proposed in the past few years [3–7] and are expected to draw more attention in the future. As opposite to digital watermarking, which requires a digital watermark to be embedded for later authentication, non-intrusive forensic analysis infers forensic information and implications from the contents

M. Sorell (Ed.): e-Forensics 2009, LNICST 8, pp. 173 – 178, 2009.

without requiring extra information, such as digital watermark, to be embedded in advance.

Among many areas of non-intrusive forensic analysis, inferring the processing pathways a piece of media, such as image or video, has undergone is one where digital forensic investigators seek traces left by various of multimedia processing tools so as to piece together evidence to support their arguments. For example, without manipulating the content, an offender could modify the metadata / header of a JPEG compressed image to make it appear to be one that has never been compressed with JPEG standards in order to mislead the investigators [6]. In this scenario, because JPEG standards requires that an image be divided into blocks of 8 × 8 pixels before applying DCT to each block, a tool that can detect the trace of 8 × 8 block operation would be helpful in defeating the offender's claim that the image had never been JPEG compressed.

A number of block artifact detection and block operation detection techniques [1, 3, 4, 7, 8] have been proposed in the recent past. The methods reported in [1] and [4] assume that the media is compressed by known standards, such as JPEG and MPEG and attempt to detect block artifacts left by the block operations with fixed block size, e.g., 8 × 8 pixels in JPEG and 16 × 16 in MPEG. This assumption imposes an application limitation of the two methods. On the other hand, without assuming fixed block size, the methods presented in [7] and [8] rely on gradient detectors to pin-point the boundaries between blocks. However, gradient detectors are known to be highly sensitive to texture and linear features such as edges and, as a result, tend to yield false positives. In [3], a pair of cross-differential filters of 2 × 2 pixels is proposed in the hope of reducing the false responses by the linear features. However, in essence the filters are variants of gradient detectors; therefore the responses to them are still prone to the influence of linear features.

In Section 2 we will proposed a new scheme that exploits the fact that *intra-block* variances is expected to be less than *inter-block* variances without assuming the size of blocks and making use of gradient detectors. Experimental results are presented in Section 3.

2 Proposed Method

In the light of the limitations inherent in the methods that rely on gradient detectors to detect boundaries, we proposed in this section a *variance-oriented block artifact detector* (VOBAD). The idea underpinning our proposed VOBAD is that the variance within the blocks boundaries (i.e., *intra-block variance*) is expected to be less significant than the variance of the pixels along the opposite sides of boundaries, (i.e, *inter-block variance*). Therefore, we want the media to respond to the VOBAD positively when the VOBAD is placed right at a block boundary, indicating that the intra-block variance is less than the inter-block variance and negatively when the VOBAD is placed elsewhere, including the places where the linear features of the media appear. Fig. 1 illustrates a 4-pixel-wide VOBAD (oriented horizontally) for detecting vertical block boundaries, as well as another (oriented vertically) for detecting horizontal block boundaries. Each double-headed arrow represents the difference/variance between its two associated pixels. The bold solid lines in the figure represent block boundaries. The response, $r_h(i, j)$, of the horizontal VOBAD is defined as

$$r_h(i,j) = \begin{cases} 1, & \text{if } 2\cdot|p(i,j)-p(i,j+1)| > \alpha\cdot(|p(i,j-1)-p(i,j)|+|p(i,j+1)-p(i,j+2)|) \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

and the response, $r_v(i, j)$, of the vertical VOBAD is defined as

$$r_v(i,j) = \begin{cases} 1, & \text{if } 2\cdot|p(i,j)-p(i+1,j)| > \alpha\cdot(|p(i-1,j)-p(i,j)|+|p(i+1,j)-p(i+2,j)|) \\ 0, & \text{otherwise} \end{cases}, \quad (2)$$

where $p(i, j)$ is the intensity at pixel (i, j) and α is greater than 1. $|p(i,j)-p(i,j+1)|$ of Eq. (1) is intended be the *inter block variance*, which correspond to the **thick** arrow in Fig. 1, while $|p(i,j-1)-p(i,j)|$ and $|p(i,j+1)-p(i,j+2)|$ are intended as *intra-block* variances, corresponding to the **thin** arrows. Eq. (2) is to be interpreted the same way. The reason the inter-block variance is multiplied by 2 is because there are two intra-block variances. According to Fig. 1, Eq. (1) and (2), we can see that we only want the horizontal VOBAD and the vertical VOBAD to return 1 when they are placed at

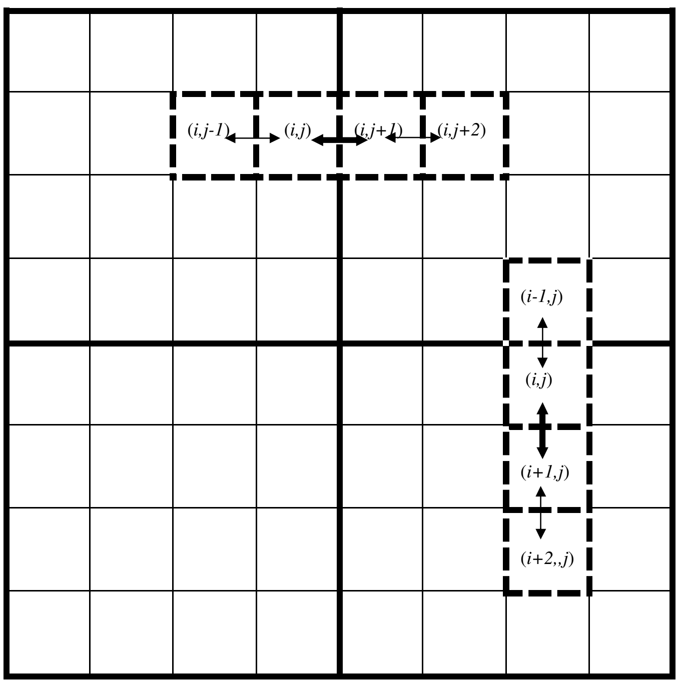


Fig. 1. Proposed *variance-oriented block artifact detectors* (VOBADs). The horizontally oriented 4-pixel-wide VOBAD is for detecting vertical block boundaries while the vertically oriented one is for detecting horizontal block boundaries. Each double-headed arrow represents the difference/variance between the two associated pixels. The bold solid lines represent block boundaries.

the *left*-hand side of and *above* a block boundary, respectively. For example, the horizontal VOBAD in Fig. 1is likely to return 1 because pixel (i, j) is at the left-hand side of the block boundary (i.e., the **thick** arrow straddles the *inter-block* boundary while each of the two **thin** arrows points to the pixels within the same block). But the vertical VOBAD is positioned below the block boundary, as a result, the **thick** arrow, corresponding to the inter-block variance in Eq. (2) points to two intra-block pixels while one of the two thin arrows point to two inter-block pixels. Therefore the response is expected to be 0, instead of 1. If the VOBAD is placed at other positions, the **thick** arrow would point to two intra-block pixels while one of the two thin arrows *may* straddle an inter-block boundary, thus likely to return 0 as well.

When the VOBADs are placed in textured areas or near/at linear features, if the thin arrows straddle inter-block boundaries and/or the thick arrows point to pixels with the same block, they would return 0. Fig. 2(b) and 2(c) show the maps of the responses of the image in Fig. 2(a) to the proposed horizontal and vertical VOBADs. The greater α of Eq. (1) and (2) is, the less noisy the response maps are. However, an α too greater than 1 is not feasible because for any processed media to be deemed acceptable in term of visual quality, the block operations should not result in noticeable difference between intra- and inter-block variances.

However, no matter what value is assigned to α of Eq. (1) and (2), it is inevitable that false responses will be picked up if the conditions match the ones in Eq. (1) and (2). Therefore after convolving the two VOBADs with the media, the next step is to pool the responses horizontally and vertically. Let us take an image of $I \times J$ pixels as an example, we pool the responses according to Eq. (3) and (4).

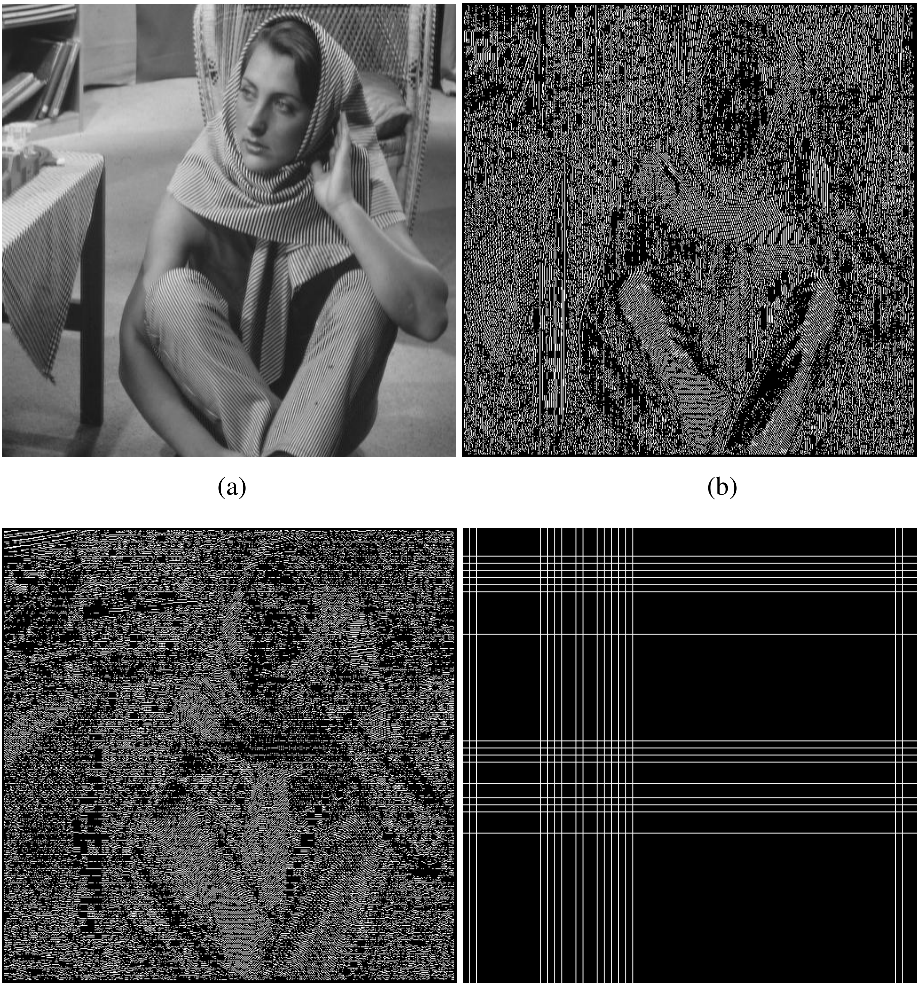
$$t_h(j) = \sum_{i=1}^{I} r_h(i, j) \qquad , j \in [1, J] \tag{3}$$

$$t_v(i) = \sum_{j=1}^{J} r_v(i, j) \qquad , i \in [1, I] \tag{4}$$

After pooling the responses, we identify n ($1 \geq n \geq J$) vertical lines and m ($1 \geq m \geq I$) horizontal lines with the highest t_h and t_v values, respectively, to get a *detection grid* like Fig. 2(d).

3 Experiments

Fig. 2 (a) shows a photo of 512 × 512 pixels compressed by Adobe Photoshop with JPEG standards at quality level 10 (highest quality level defined by Adobe Photoshop). Fig. 2(b) and (c) show the responses to the horizontal and vertical VOBADs, respectively. Note that to avoid extending the VOBADs beyond image borders we do not apply the VOBADs to the first and last two columns and rows of the images. We set parameter α of Eq. (1) and (2) to 1.5 in the experiment that yields Fig 2(b) and 2(c). Our other experiments suggest that the range [1.0, 2.0] is a reasonable choice. Fig. 2(d) shows the block detection grid after pooling responses vertically and horizontally. The n (=16) vertical lines and m (=16) horizontal lines in



(a) (b)

(c) (d)

Fig. 2. Experimental results of block artifact detection (image size is 512 × 512). a) image compressed by Adobe Photoshop at quality level 10 , b) responses to horizontal VOBAD, c) responses to vertical VOBAD, d) block detection grid.

Fig. 2(d) with the highest *pooled* responses t_h and t_v values, respectively, clearly indicate that they correctly appear at the positions of multiples of 8. Although multiples of 8 are also multiples of 2 and 4, but if the correct block size were 2 (or 4), then some of the detected lines should have appeared at positions of multiples of 2, 6 10, 12, etc (or 4, 12, etc), which are not multiples of 8. Being unable to find lines appearing at those positions suggests that the image has undergone an 8 × 8 block operation, which conforms to JPEG standards.

4 Conclusions

In this work we have briefly reviewed a number of non-intrusive forensic methods for detecting block artifacts and pointed out their features as well as limitations. We observed that assuming fixed block size limits the applicability of the schemes while the use of gradient detectors is too sensitive to texture and linear features such as edges. In the light of the limitations inherent in the reviewed methods, we proposed a pair of *variance-oriented block artifact detectors* (VOBADs), which exploit the fact that intra-block variances are less than inter-block variances. The experimental results presented in this work have shown the efficacy of the proposed scheme.

References

1. Fan, Z., de Queiroz, R.: Identification of bitmap compression history: JPEG detection and quantizer estimation. IEEE Trans. on Image Processing 12(2), 230–235 (2003)
2. Li, C.-T., Li, Y., Wei, C.-H.: Protection of digital mammograms on PACSs using data hiding techniques. International Journal of Digital Crime and Forensics 1(1), 75–88 (2009)
3. Luo, W.Q., Huang, J., Qiu, G.: A novel method for block size forensics based on morphological operations. In: International Workshop on Digital Watermarking (2008)
4. Luo, W.Q., Wu, M., Huang, J.W.: MPEG recompression detection based on block artifacts. In: SPIE Electronic Imaging, Security, Steganography, and Watermarking of Multimedia Contents, vol. 6819 (2008)
5. Sorell, M.: Unexpected Artifacts in a Digital Photograph. International Journal of Digital Crime and Forensics 1(1), 45–58 (2009)
6. Sorell, M.: Digital camera source identification through JPEG quantization. In: Li, C.-T. (ed.) Multimedia Forensics and Security, IGI Global, pp. 291–313 (2008)
7. Tjoa, S., Lin, W., Zhao, H., Liu, K.: Block size forensic analysis in digital images. In: IEEE International Conference on Acoustics, Speech and Signal Processing, vol. 1, pp. I-633–I-636 (2007)
8. Wang, Z., Bovik, A., Evan, B.: Blind measurement of blocking artifacts in images. In: IEEE International Conference on Image Processing, vol. 3, pp. 981–984 (2000)