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Robust image hashing based on color vector angle and Canny operator

Zhenjun Tang [a,b,*], Liyan Huang [a,b], Xianquan Zhang [a,b], Huan Lao [a,b]

[a] Guangxi Key Lab of Multi-source Information Mining & Security, Guangxi Normal University, Guilin 541004, China
[b] Department of Computer Science, Guangxi Normal University, Guilin 541004, China

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ABSTRACT

Image hashing is a novel technology of multimedia processing, and finds many applications, such as image forensics, image retrieval and image indexing. Conventional image hashing algorithms have limitations in reaching desirable classification performances between rotation robustness and discrimination. Aiming at this issue, we propose a robust image hashing based on color vector angle and Canny operator. Specifically, our hashing firstly converts input image to a normalized image by interpolation and Gaussian low-pass filtering. And then, color vector angles and image edges are both extracted from the normalized image. Finally, statistical features incorporating color vector angles and image edges are calculated to form image hash. We conduct experiments with 2762 images to validate efficiency of our hashing. The experimental results show that our hashing is robust against normal digital processing, such as image rotation, brightness/contrast adjustment and JPEG compression, and reaches good discrimination. Receiver operating characteristics (ROC) curve comparisons with some state-of-the-art algorithms indicate that our hashing outperforms these compared algorithms in classification performances between robustness and discriminative capability.

1. Introduction

Image hashing is a new and hot topic of multimedia processing. It uses a short string called image hash to denote an image, and has been widely applied to many applications [1], such as image authentication, image forensics, image retrieval, image indexing and image copy detection. In practice, digital images often undergo some normal processing such as JPEG compression, geometric transform, and format conversion. After these processing, visual appearances between the original and processed images are unchanged, but digital representations are quite different. So their image hashes are expected to be the same or very similar. In general, image hashing has two basic properties [1–3] as follows. (1) *Perceptual robustness*: Image hashing should map visually identical images to the same or very similar hashes regardless of their digital representations. In other words, image hash should be robust against normal digital processing, such as image compression and image enhancement. (2) *Discriminative capability*: For different images, image hashing should produce different image hashes. Except these basic properties, image hashing must satisfy other property for some specific applications. For example, it should be secure enough (e.g., controlled by keys) for application to image forensics.

In the past years, many researchers have devoted themselves to developing image hashing. The pioneer work was introduced by Schneider and Chang [4]. From then on, image hashing has attracted much attention in multimedia community. At first, researchers used discrete wavelet transform (DWT), discrete cosine transform (DCT) and discrete Fourier transform (DFT) to develop image hashing. For example, Venkatesan et al. [5] exploited DWT coefficients statistics to construct image hashes. This algorithm is robust against JPEG compression, median filtering and rotation within 2°, but fragile to gamma correction and contrast adjustment. Fridrich and Goljan [6] used DCT coefficients to design hashing function. This method is sensitive to image rotation. Swaminathan et al. [7] used DFT coefficients to produce image hashes. This hashing can resist digital processing such as moderate geometric transforms and filtering. Monga and Evans [8] detected visually significant feature points with the end-stopped wavelet transform and exploited them to construct hashes. Later, Radom transform (RT) was also taken for hash generation. For example, Lefèbvre et al. [9] were the first of using RT to design image hashing. Motivated by RT, Roover et al. [10] introduced a RASH method based on radial projections of image pixels and 1-D DCT. This scheme is robust to rotation, but its discrimination is not good enough. In another work, Ou and Rhee [11] applied RT to input image, randomly selected 40 projections to perform 1-D DCT, and took the first AC coefficient of each projection

* Corresponding author at: Department of Computer Science, Guangxi Normal University, 15 Yucai Road, Guilin 541004, PR China. Tel.: +86 15295990968.
E-mail address: tangzj230@163.com (Z. Tang).

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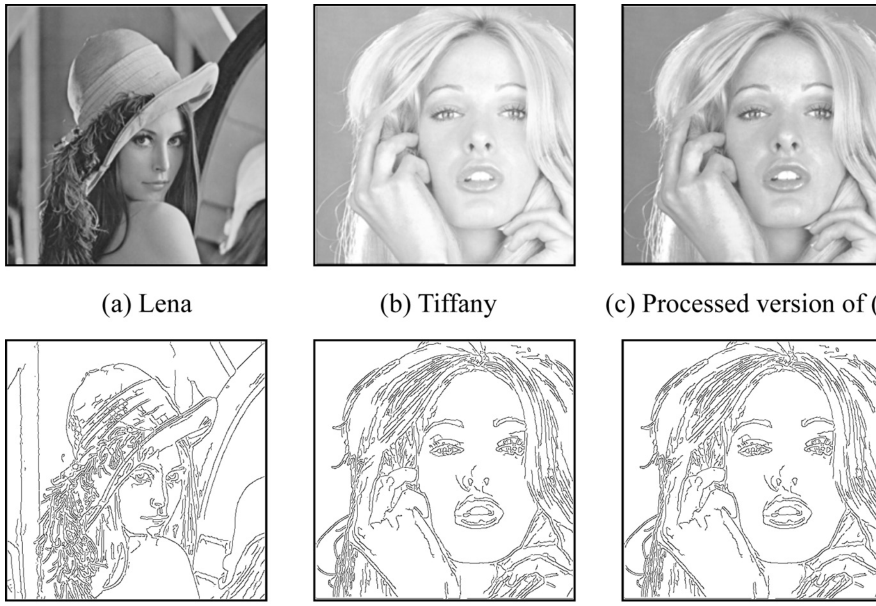

(a) Lena (b) Tiffany (c) Processed version of (b)

(d) Edge of (c) (e) Edge of (b) (f) Edge of (c)

Fig. 1. Standard test images and their edges.

to produce hash. The RT-DCT hashing is resistant to rotation within 5°.

Besides the above strategies, researchers also applied other techniques to image hashing. For example, Kozat et al. [12] viewed image and attacks as a sequence of linear operators, and proposed to calculate hashes with singular value decompositions (SVDs). The SVD–SVD hashing is robust to rotation at the cost of significantly decreasing discrimination. Monga and Mihcak [13] firstly proposed to use non-negative matrix factorization (NMF) to derive image hashing, and obtained a high performance algorithm. This hashing is resilient to geometric attacks, but it cannot resist some normal manipulations, e.g., watermark embedding. Tang et al. [14] designed a lexicographical image hashing based on DCT and NMF. This algorithm is resilient to image rotation within 1°. Recently, Li et al. [15] calculated hashes using random Gabor filtering (GF) and dithered lattice vector quantization (LVQ). The GF–LVQ hashing is resistant to JPEG compression and rotation, but its discrimination is not good enough. Tang et al. [16] calculated histogram of color vector angles (HC) and compressed it by DCT. The HC-DCT hashing can tolerate rotation with any angle, but its discrimination is still not desirable. In another work [17], Tang et al. proposed a robust hashing with local image entropies and DWT. This approach can tolerate rotation within 5°. Laradji et al. [18] exploited quaternion Fourier transform (QFT) to construct image hashes. The QFT hashing is also sensitive to rotation. Zhao et al. [19] exploited Zernike moments (ZM) to calculate image hashes. The ZM-based hashing only tolerates rotation within 5°. Tang et al. [20] presented a robust image hashing with local moment invariants. This method can only tolerate rotation with 2°.

From the above review, it is found that most hashing algorithms are sensitive to rotation or robust against small angle rotation, such as [5,6,8,14,17–20]. Some methods can tolerate rotation with any angle, but their discriminations are not good enough, such as [9,15,16]. Therefore, it is still a challenging task to develop hashing method reaching a desirable trade-off between rotation robustness and discrimination. In addition, most algorithms are designed for gray images. For color images, they often choose the luminance component in YCbCr color space for representation. As other color components are discarded, their discriminative capability is limited. Aiming at these problems, we propose a robust image hashing based on color vector angle and Canny operator. Our algorithm can reach good rotation robustness since our features extracted from circles are invariant to rotation. Moreover, the use of color vector angle provides our algorithm a desirable discrimination. This is because color vector angle takes all RGB color components into account and then makes our method discriminative. We conduct experiments with 2762 images (i.e., 2562 images for robustness and 200 images for discrimination) to validate our efficiency. Experimental results indicate that our hashing reaches good trade-off between rotation robustness and discrimination, and outperforms some state-of-the-art hashing algorithms.

The rest of this paper is organized as follows. Section 2 describes the proposed image hashing. Sections 3 and 4 present the experimental results and performance comparisons, respectively. Conclusions are finally drawn in Section 5.

2. Proposed image hashing

A key step of image hashing is to extract robust feature invariant to normal digital processing. Clearly, edge is an important visual image feature and human visual system (HVS) can distinguish images in terms of their image edges. For example, Fig. 1(a) and (b) are two standard test images and (d) and (e) are their image edges. Although gray information is discarded in (d) and (e), HVS can also recognize that (a) is different from (b) according to their edge pixels' distribution. In addition, we find that image edge is almost kept unchanged after normal digital processing. For example, we decreased the brightness of Tiffany with Photoshop and obtained a processed version as shown in Fig. 1(c). Then, we detected image edge of Fig. 1(c) by Canny operator and generated the edge image as shown in Fig. 1(f). It is observed that there is no significant difference between Fig. 1(e) and (f). In other words, image edges of Fig. 1(e) and (f) are almost the same. Considering that edge can help to distinguish different images and is almost the same after normal digital processing, we investigate the use of image edge and thus propose a robust image hashing with color vector angle and image edge.

Our image hashing consists of three steps, as shown in Fig. 2. In the first step, input image is converted to a normalized image for