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Perceptual image hashing via dual-cross pattern encoding and salient structure detection

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ABSTRACT

In this paper, we propose a robust image hashing scheme based on perceptual texture and structure features. Through pre-processing, the input image with arbitrary size is regularized as a secondary image to alleviate the influence of noises. Then, the encoding of dual-cross pattern (DCP) is conducted on the secondary image to produce two coded maps representing textural information in horizontal-vertical and diagonal directions, respectively, and the DCP-based textural features can be extracted with the assist of histogram composition. On the other hand, salient structural features can be extracted from the frequency coefficients and position information of selective-sampled blocks containing the richest corner points. The final hash can be obtained after dimension reduction for the two types of extracted features. Experimental results demonstrate that our scheme has better performances with respect to robustness, anti-collision, and efficiency than some of state-of-the-art schemes.

1. Introduction

Nowadays, the popularization of imaging devices, such as digital camera, scanner and mobile phone, makes the acquisition of digital images more conveniently than before. In the mean time, the trustworthiness risk of image contents continues to increase with the widespread applications of image editing tools. Consequently, in recent years, the authentication for multimedia contents inevitably becomes an important issue in the fields of multimedia information security and related applications, and digital right management (DRM) for digital images is also in demand, especially for the protection of image integrity [11,18]. These practical issues lead to the emergence of relevant techniques, which can be generally categorized into three types: fragile image watermarking [9,16,17], image forensic [4,27,29] and image hashing [1,8,28].

Fragile image watermarking often generates watermark data that is related with the principal contents of images and embeds the watermark data into original image in an imperceptible way. However, due to the operation of data embedding, it is unavoidable to cause visual degradation of image quality. As for image forensic technique, it usually analyzes the intrinsic traces and statistical characteristics of suspicious images, and concentrates on verifying the authenticity, which has the

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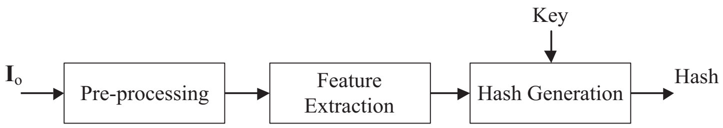

Fig. 1. Flowchart of image hashing scheme.

disadvantages about the lack of accuracy accompanying with high computation complexity. In this work, we mainly focus on the technique of perceptual image hashing. Perceptual image hashing, also known as robust image signature, can map an original image into a compact short sequence, which can be considered as a digital digest of principal contents for the image. Although traditional cryptographic hash functions, such as MD5 and SHA-1, can also convert input message into a short string, they are extremely sensitive to even one bit change. Content-preserving image manipulations may modify the digital representations of images, however, the perceptual contents of images are not changed. Therefore, compared with traditional cryptographic hash functions, image hashing is more feasible to the applications of content authentication and tampering detection for digital images. Also, through comparing the compact hash sequences of the images in databases, image hashing can be effectively utilized for image classification and retrieval.

Generally speaking, an ideal image hashing scheme consists of three main steps, i.e., pre-processing, feature extraction and hash generation, as illustrated in Fig. 1. The crucial step of perceptual image hashing is based on the well-designed image features that should be in accordance with perceptual characteristics of human visual system (HVS). Denote an original image as $\mathbf{I}_o$, a perceptually identical version of $\mathbf{I}_o$ as $\mathbf{I}'$, and a visually distinct version of $\mathbf{I}_o$ as $\mathbf{I}_d$. The image hashing scheme with a secret key K is represented as $\mathrm{H}_K(\bullet)$. Thus, four desirable properties for an ideal $\mathrm{H}_K(\bullet)$ can be summarized as follows.

(1) *Perceptual robustness*: $\Pr\{\mathrm{H}_K(\mathbf{I}_o)=\mathrm{H}_K(\mathbf{I}')\} \geq 1-\varepsilon_1$. Image hashing should map visually identical images to the same or very similar hash no matter their digital representations. That is to say, it should be computationally feasible for image hashing scheme to be robust against common content-preserving operations on images.
(2) *Anti-collision capability*: $\Pr\{\mathrm{H}_K(\mathbf{I}_o)=\mathrm{H}_K(\mathbf{I}_d)\} \leq \varepsilon_2$. For visually distinct images, image hashing should generate significantly different hashes. In other words, the probability for the two image hashes of two visually distinct images being the same should be close to zero in an image hashing scheme.
(3) *Compactness performance*: $\mathrm{Size}(\mathrm{H}_K(\mathbf{I}_o)) << \mathrm{Size}(\mathbf{I}_o)$. The size of the generated image hash should be much smaller than the size of original image, thus, storage space can be saved and transmission efficiency can be increased when the image hash is attached with original image for image authentication or retrieval.
(4) *Key-dependent security*: $\Pr\{\mathrm{H}_{K1}(\mathbf{I}_o)=\mathrm{H}_{K2}(\mathbf{I}_o)\} \leq \varepsilon_3$. The outputs of image hashing scheme with different keys must be significantly distinct, which means the security of image hashing scheme should depend on the secret key. Without the knowledge of correct secret key, no one can forge the image hash that can pass through the authentication.

Here, $\Pr\{\cdot\}$ denotes the calculation of probability, and ε_1, ε_2 and ε_3 are three positive numbers that are close to zero.

Therefore, an image hashing scheme with excellent performance should achieve a trade-off between perceptual robustness and anti-collision capability. Besides these two basic properties, image hashing should also satisfy other properties, including compactness and key-dependent security, for some specific applications. In this paper, in order to achieve better performances, we propose an image hashing scheme based on perceptual texture-structure features. In our scheme, original image is first regularized through resizing and filtering, and then singular value decomposition (SVD) is conducted on the regularized result to produce a secondary image. Then, the calculation of dual-cross pattern (DCP) is applied on the secondary image to extract perceptual texture features. In the meantime, a series of non-overlapping image blocks containing the richest structural information with Harris corner points are sampled. Dominant frequency coefficients of these representative sampled blocks and their corresponding position information are retrieved as salient structural features. The final secure image hash can be obtained after data compression with dimensionality reduction for the extracted, textural and structural features, which is robust to common content-preserving operations and achieves very low collision probability simultaneously. In summary, the main contributions of this work lie on the following four aspects: (1) Both textural and structural features of the secondary image are considered in the image hashing scheme; (2) Textural features based on DCP-coded maps and structural features based on sampled blocks can effectively represent perceptual contents of images; (3) Better performances of robustness and discrimination can be achieved through the secure, compressed texture-structure features; (4) Our hashing scheme has high computation efficiency and reasonable hash length simultaneously.

The rest of this paper is organized as follows. Section 2 reviews state-of-the-art schemes for image hashing. Section 3 describes the proposed image hashing scheme detailedly, including the procedures of pre-processing, perceptual feature extraction and hash generation. Experimental results and analysis are given in Section 4. Section 5 concludes the paper.

2. Prior works

Many researchers have devoted to studying image hashing in the past, and spread across the decades up to the present. As far, a number of image hashing schemes therefore have been presented [3,5,10–15,19,20,21,24–26]. The pioneer work of image hashing by Schneider and Chang introduced a robust method of image content based on digital signature and can