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Robust watermarking against geometric attacks using partial calculation of radial moments and interval phase modulation

Sasan Golabi, Mohammad Sadegh Helfroush *, Habibollah Danyali, Mehri Owjimehr

Department of Electrical and Electronics Engineering, Shiraz University of Technology, Shiraz, Iran

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ABSTRACT

This paper presents a new image watermarking scheme which is blind and robust against geometric attacks. The proposed algorithm is based on the features of radial moments. In this algorithm the radial moments were first computed and then the watermark was embedded into the differential phase of various blocks of the original image using a special type of PSK modulation called interval phase modulation (IPM). In order to embed the watermark into the phase of moments, a particular method, namely the partial calculation of moments was utilized for computation. The implementation results show the improvement in the robustness and quality of the watermarked images in comparison with other methods.

1. Introduction

The rapid growth of multimedia applications leads to an urgent need for adequate copyright protection techniques, especially for image data. Robust watermarking can be used to trace copies or to implement copyright protection methods. Some watermarking algorithms are published in order to satisfy this robustness requirement [2,7,13–15,18].

For robust watermarking schemes, the embedded watermark must be robust against a variety of possible attacks. These include robustness against signal processing attacks, such as filtering, additive noise, cryptographic, statistical and geometric attacks. While many methods have a good performance against signal processing attacks, they lack robustness to geometric transformations. Rotation and scaling attacks are considered more challenging than other attacks. This is due to the fact that changing the image size or its orientation even slightly, could dramatically reduce the receiver ability to retrieve the watermark. It has been proven that even very small geometric distortions can prevent the detection of a watermark [12,16,19,22].

The existing methods that can resist geometric attacks are classified into the exhaustive search, invariant domain, embedding template and feature-based methods. One concern in the exhaustive search is the computational cost in larger search space. Invariant domain methods usually suffer from implementation issues and are vulnerable to cropping. The embedding template-based techniques are vulnerable to template estimation attacks and cropping. By contrast, the feature-based watermarking techniques use image-dependent features to represent invariant reference points for both embedding and detection. They are resistant to various attacks, including cropping and random bending attacks (RBA) by binding the watermark synchronization with the image salient characteristics. These characteristics may be the whole image, some local regions, or feature points. This group of the watermark synchronization techniques, also known as the second generation

* Corresponding author.
E-mail addresses: s.golabi@sutech.ac.ir (S. Golabi), ms_helfroush@sutech.ac.ir (M. S. Helfroush), danyali@sutech.ac.ir (H. Danyali), m.owjimehr@sutech.ac.ir (M. Owjimehr).

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watermarking [22], has the worthwhile properties of invariance to noise, geometrical transformation and localization. This group of techniques can be divided into three sub-categories: moment-based, histogram-based and feature point-based.

Histogram-based watermarking techniques [3] use histograms to solve the geometric invariance problem. The histogram distribution of an image is approximately invariant under geometric attacks. Xiang et al. [19] propose an invariant image watermarking in the low-frequency domain by using the histogram shape and mean in the Gaussian filtered low-frequency component of images. The method proposed in [3] developed a geometrically robust image watermarking scheme by using a histogram in a certain range to embed a watermark in circular regions centered on the Harris–Laplace feature points. The major limitation of the histogram-based methods is their incapability to resist local transformation.

Feature point-based watermarking methods use the feature points to form local regions for the embedding and extracting of the watermark. In [17], first, disks which represent the features of the image will be derived and 16 watermark bits will be embedded in each of them by an indirect method. For example, the number of disks extracted for the image Lena is 8 and for the pepper is 4. For watermark extraction, it is required that the exact location of the feature disks be identified. Due to computational errors (the interpolation errors in the normalization process and the sampling errors in converting formulas from continuous to discrete ones), the disks cannot be located accurately. Hence, this method is usually used only to detect the presence of the watermark rather than extract it. In [4], two blind and non-blind watermarking methods are provided. In the blind method, the desired watermark will be changed with respect to the normalized original image. Then an inverse normalization operation is applied to the created watermark. Therefore, the watermark image and the host image will be of the same size. Now, the watermark is added to the host image. Due to applying the normalization to the watermark image, the normalization effects on the original image will be canceled. However, in these methods, watermark extraction involves finding the exact position of regions and because of the interpolation and normalization errors, this could not be performed accurately.

Due to their ability to represent the global properties of the image, moments have been used in many application fields of image processing. Geometric moments are mainly used to capture global features of images. In [9], the absolute values of the Zernike moments which are extracted from the normalized image are used for watermark embedding. These features are invariant to geometric changes. The watermark will be changed and embedded into the host image using these features. In [5], to achieve robustness against affine transformation, the watermark is embedded into a moment-based normalized image. In [1,20], Zernike moments are used as geometrically robust image watermarks. Zhang et al. in [21] propose a geometric invariant blind image watermarking by using invariant Tchebichef moments and independent component analysis (ICA). In [10], a geometrically invariant watermarking method is proposed based on the orthogonal moments obtained by polar harmonic transform (PHT). The magnitude of these moments is rotation invariant. However, they are not strictly translation and scale invariant. To achieve these properties, the image needs to be resized to a domain $(x, y) \in [-1\,1] \times [-1\,1]$ which increases the numerical and interpolation errors. Moreover, they have used direct modification of moments which is less desirable in comparison with change indirectly the spatial pixels. A compensation image is proposed to solve the reconstruction problem. Not only, it raises the complexity; but also, there is a limitation for the increasing of the PSNR.

Invariant moment-based methods have low computational costs and do not need the complete normalization of the image. As the normalization process is one of the main sources of numerical errors, the features extracted by moments are more accurate and robust against common geometric and signal processing attacks than other methods. However, moment-based techniques are highly fragile against cropping attacks.

In this paper, a new robust watermarking scheme, which can effectively resist common geometric attacks, is proposed. The phase of adaptive radial moments, which in this paper is computed in a unit circle, is used for watermark embedding. According to the new phases after watermark embedding, pixels will be changed in the spatial domain. These phases are robust against geometric attacks and therefore no normalization procedure is needed. Therefore, the computational cost is low; moreover, the numerical accuracy will be high. Using a special type of phase modulation, called "interval phase modulation (IPM)", increases robustness against compression attacks. The results of implementation show the improved quality of the watermarked image and more capacity, as compared with other common geometric invariant methods.

The rest of this paper is organized as follows: in Section 2, moments, particularly, radial moments and their invariant feature extraction will be reviewed. In Section 3, the watermark embedding and extraction procedures are explained. Implementation and results are described in Section 4 and finally Section 5 provides the conclusion for this work.

2. Moments

The most common moments, are geometric moments which can be calculated as:

$$M_{pq} = \iint_R f(x,y)x^p y^q \, dxdy \tag{1}$$

where $f(x, y) \geqslant 0$ is a real bounded function with support on a finite region R; M_{pq} is the geometric moment of the order $(p + q)$. In the discrete case, for a digital image of size $N \times N$ we have:

$$M_{pq} = \sum_x^N \sum_y^N f(x,y)x^p y^q \tag{2}$$