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An image watermarking scheme in wavelet domain with optimized compensation of singular value decomposition via artificial bee colony

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ABSTRACT

Digital image watermarking is the process of authenticating a digital image by embedding a watermark into it and thereby protecting the image from copyright infringement. This paper proposes a novel robust image watermarking scheme developed in the wavelet domain based on the singular value decomposition (SVD) and artificial bee colony (ABC) algorithm. The host image is transformed into an invariant wavelet domain by applying redistributed invariant wavelet transform, subsequently the low frequency sub-band of wavelet transformed image is segmented into non-overlapping blocks. The most suitable embedding blocks are selected using the human visual system for the watermark embedding. The watermark bits are embedded into the target blocks by modifying the first column coefficients of the left singular vector matrix of SVD decomposition with the help of a threshold and the visible distortion caused by the embedding is compensated by modifying the coefficients of the right singular vector matrix employing compensation parameters. Furthermore, ABC is employed to obtain the optimized threshold and compensation parameters. Experimental results, compared with the related existing schemes, demonstrated that the proposed scheme not only possesses the strong robustness against image manipulation attacks, but also, is comparable to other schemes in term of visual quality.

1. Introduction

The expansion of Internet and computer networks have made the digital media (e.g. audio, video, image, etc.) acquisition and distribution very easy these days. The digital contents having the same quality as that of the original can be created easily with the help of advanced multimedia technologies. This sometimes leads to crucial critical issues of misuse of digital content leading to severe consequences. To overcome this problem, digital watermarking has been introduced as a safeguard for the copyright protection [13,39]. Numerous efforts have been devoted to the advancement of the image watermarking schemes [3,7,8,11,19,54,59,63]. Watermarking schemes can be categorized as per their characteristic of implementation and the requirements for the extraction of the watermark, a detailed review is provided in [25,29].

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The prime objective of a robust watermarking scheme is to preserve the quality of the watermarked image (i.e. imperceptibility) while protecting the watermark when the watermarked image undergoes to intentional or unintentional threats. Therefore, a robust watermarking scheme is the one in which the watermark stays intact with the content of the host image when it is subjected to different distortions or attacks like rotation, row or column flipping, scaling, and translation. Several image watermarking schemes are proposed in the literature, improving these two features by taking the advantages of different transforms, such as the discrete Fourier transform (DFT), discrete fractional Fourier transform (DFrFT), discrete wavelet transform (DWT), discrete cosine transform (DCT), singular value decomposition (SVD), and their combinations [3,5,13,14,16,18,23,32,33,43,44,49,52,63,66]. In [60] a feature-based image watermarking technique by using multi-scale Harris detector and wavelet moment theory is proposed. The digital watermark is embedded in the local feature regions of the host image by modifying the selected wavelet moment invariants. An improved dual color image watermarking scheme based on SVD employing the concept of the relationship between the second and third elements of the first column of the eigenvectors has been introduced by Su et al. [55]. All the aforementioned DWT watermarking methods are not invariant to rotation and flipping attacks applied to the watermarked image. Li et al. [35] proposed a redistributed invariant discrete wavelet transform (RIDWT) domain image watermarking. The invariant wavelet domain is obtained by relocating the pixels' position to new one, then applied Haar wavelet transform and image normalization. This transform is invariant to the rotation of multiple of 90°, row and column flipping. Excited by its performance in terms of robustness and imperceptibility authors have recommended its application in other wavelet based watermarking schemes.

In the last two decades, artificial intelligence (AI) techniques such as evolutionary algorithms (EAs), support vector machine, fuzzy logic and neural networks have played an important role in real life applications, including image watermarking [1,3,10,12,24,41,42,56,58,59,62,64] for improving the performance. Under the category of evolutionary algorithms, genetic algorithm (GA), particle swarm optimization (PSO), differential evolution (DE), and Firefly algorithm have made numerous valuable contributions to the field of watermarking. An image watermarking technique which uses GA to find the optimal scaling factors for watermark insertion is designed by Lai [31]. In [47], the introduced technique is making use of a simple genetic algorithm in order to optimize the set of parameters for moments that significantly influences the locality properties alongside with the overall performance of the watermarking procedure. In [51,61], PSO is used to find the scaling factors and thresholds respectively for watermark embedding. Applications of DE algorithm for finding the optimal parameters for image watermarking can be found in [3,5,6]. Recently, Agarwal et al. [1] implemented Firefly algorithm to find the optimal values of multiple scaling factors (MSFs) for watermark embedding. A relatively new member of evolutionary algorithms, artificial bee colony (ABC), was introduced by Karaboga [27] in 2005. It simulates the intelligent foraging behavior of a honey bee swarm. Numerical comparisons demonstrated that the performance of ABC algorithm is competitive to other population-based algorithms with an advantage of employing fewer control parameters [28]. Due to its simplicity and ease of implementation, ABC algorithm has captured much attention and has been applied to solve many practical optimization problems [2,15,22,34,50]. It is worth pointing out that the ABC for the optimization problems in image processing such as segmentation [22], and enhancement [15] has been implemented, where it has given a good performance. But to the best of our knowledge, it has never been practiced in image watermarking.

The literature review of SVD based image watermarking reveals that, the watermarking schemes developed in spatial domain or frequency domain, generally embed singular values of the watermark and the rest of the information is kept safe for its extraction. Various researchers pointed out the false positive detection problem in most of the SVD-based algorithms and proved that the verification watermark unreasonably can be extracted [4,20,21,36–38]. This creates an ambiguous situation, indicating the futility of such schemes for copyright protection purpose. To overcome this problem, numerous researchers have proposed improved versions of SVD based image watermarking schemes. A robust image watermarking scheme based on SVD that embeds the entire watermark is proposed by Mohammad et al. [45]. Run et al. [51] introduced an image watermarking scheme employing SVD and embedding the principal component of the watermark. Particle swarm optimization is applied to get the optimal scaling factors for embedding. It is based on the fact that SVD subspace (left and right singular vectors) can preserve a significant amount of information about an image. Because different regions of an image have different local features, so some visual models may be incorporated in finding the suitable embedding regions to improve robustness while maintaining imperceptibility. Based on this concept, a blind SVD-based watermarking scheme is presented in [9]. The host image is segmented into non-overlapping blocks of size 8×8, then the embedding blocks (most textured) are selected depending upon the number of non-zero singular values. The watermark bits are embedded by modifying the coefficients in the first column of the left singular vector matrix of the target blocks. Lai [30] has introduced an image watermarking scheme based on human visual system (HVS) and SVD. The embedding process of the scheme is same as of [9], while the embedding blocks are selected based on the sum of visual and edge entropies. The scheme of Fan et al. [17] is an advanced version of the scheme proposed by Chang et al. [9], that promoted the transparency of the scheme by incorporating compensation operation. According to their scheme, the damage in the quality due to insertion of the watermark in the left singular vector matrix is compensated by modifying the right singular vector matrix. However, though these SVD based watermarking schemes have solved the false positive detection problem, they are not robust against various attacks and distortions. Moreover, in the watermarking scheme proposed by Fan et al. [17], the threshold and compensation parameters are tuned and adjusted manually. The proper setting of these parameters for watermarking is more difficult than expected, that generates significant optimization challenges.

In view of the above facts, this paper proposes a robust image watermarking scheme developed in an invariant wavelet domain based on the singular value decomposition (SVD) and the artificial bee colony (ABC) algorithm. The RIDWT is applied