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Robust logo watermarking using biometrics inspired key generation

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ABSTRACT

In this paper, a novel logo watermarking technique with key concept is proposed using fractional wavelet packet transform (FrWPT), non-linear chaotic map and singular value decomposition (SVD). The core idea is to use biometrically generated keys in the embedding process of gray-scale watermark. Therefore, this paper first proposes a method for generating keys from biometrics efficiently. Then the host image is first randomized with the help of non-linear chaotic map followed by the embedding in the FrWPT domain by modifying the singular values of the randomized image. Further, in order to enhance the security, an authentication key is formed to authenticate the watermarked image. Finally, a reliable extraction process is proposed to extracted watermark from the possibly attacked authenticate watermarked image. The security, attack and comparative analysis confirm high security, efficiency and robustness of the proposed watermarking technique. Further, an efficient solution is also proposed to deal with the ambiguous situations created by SVD in watermarking.

1. Introduction

The success and substantial proliferation of the web technologies have created an environment in which some of very crucial issues for digital media such as illegal copying, distribution, editing, copyright protection and authentication have become very easy. One of the possible solution to prevent these issues is encryption, which essentially protects content during the transmission of digital data. However, the digital media is no longer protected as soon as the media is decrypted. This fact primarily motivated the development of watermarking techniques (Cox, Miller, & Bloom, 2002). The watermarking is a process to embed or insert a piece of information, generally called watermark, into a digital media. Thus, the goal of watermark is to be always present in the media and resolve the dispute whenever the intellectual property right is in question. The whole process is done in such a manner that it will not degrade the quality of the digital media.

A variety of watermarking algorithms have been proposed in the literature. These algorithms can be broadly classified in two categories according to the embedding domain: spatial and transform domain. Spatial domain approaches (Hwang, Chang, & Hwang, 1999; Tsai, Huang, & Kuo, 2011; Wang, Peng, & Shi, 2011) are the simplest and the earliest algorithms based on the modification of pixel intensities. These algorithms are less robust against the attacks. On the other hand, transform domain approaches insert the watermark into transform coefficients, such as Fourier transform (Cox, Killian, Leighton, & Shamoon, 1997; Solachidis & Pitas, 2004), cosine transform (Lin, Lee, & Chang, 2009; Suhail, Obaidat, Ipson, & Sadoun, 2003), wavelet transform (Chou & Liu, 2010; Cui & Li, 2011; Kundur & Hatzinakos, 2004; Ouhsain & Hamza, 2009; Rahman, Ahmad, & Swamy, 2009; Wang, Doherty, & Dyck, 2002; You, Du, Cheung, & Chen, 2010), Hadamard transform (Maity & Kundu, 2011), quaternion principal component algorithm (Lai & Tsai, 2010; Lang, Zhou, Cang, Yu, & Shang, 2012), fractional Fourier transform (Delong, 2009; Feng, Xiaomin, & Shouyi (2005)), fractional wavelet transform (Bhatnagar & Raman, 2009a), fractional dual tree complex wavelet transform (Bhatnagar & Wu, 2013), curvelet transform (Zhang, Cheng, Qiu, & Cheng, 2008), etc.

Recently, a new transform, singular value decomposition (SVD)-based watermarking technique and its variants have been proposed (Chandra, 2002; Liu & Tan, 2002). These approaches work on the simple concept of finding the SVD of a cover image or the SVD of each block of the cover image, and then modifying the singular values to embed the watermark. Further, some researchers have presented hybrid watermarking schemes in which they have combined SVD with other existing transforms (Ganic & Eskicioglu, 2005; Sverldov, Dexter, & Eskicioglu, 2005). The main reason behind the hybridization is the fact that SVD based scheme withstands a variety of attacks but has limited robustness against

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geometric attacks like rotation, cropping etc. Hence, for improving the performance, hybridization is needed. Thereafter, a variety of hybrid schemes are proposed (Bhatnagar & Raman, 2009b, 2009c, 2010; Bhatnagar, Raman, & Wu, 2012; Lai & Tsai, 2010). It was however first argued in Wu (2005), that by taking recourse to the reference matrices of the watermark, the same can be extracted from a possibly distorted watermarked image and this leads to an ambiguous situation where a non-existent watermark is incorrectly deemed to exist in the watermarked image.

The main stressed motive of this work is to develop and implement a new concept in SVD based hybrid watermarking scheme which rectifies the ambiguity problem and provide better robustness when compared to peer's schemes. The core idea is to use the biometrics-driven keys in the SVD based hybrid watermarking scheme such that if someone has the knowledge of full embedding process except these keys then he/she can never extract the watermark. In the proposed work, these keys are generated by the biometrics of the owner/user of the digital-media. Biometrics (Jain, Bolle, & Pankanti, 1999; Jain, Ross, & Pankanti, 2006) is the recent advancement in the area of information technology and is gaining increasing interest of research as well as corporate community. Biometrics refers to methods that can be used for uniquely recognizing individuals based upon their one or more intrinsic physical or behavioral characteristics. In information technology, in particular, biometrics is used as a tool for efficient and reliable identity management and access control (Jain & Uludag, 2006; Uludag, Pankanti, & Prabhakar, 2004). Therefore, the development of a digital media security system is proposed in this work which will use the biometrics as an actuating factor to strengthen the security.

In this work, a new watermarking scheme using fractional wavelet packet transform and singular value decomposition is proposed in which the watermark is a visually meaningful gray scale logo instead of a noise type Gaussian sequence. The basic idea is to capture an appropriate biometrics of the user/owner followed by the biometrics inspired key generation. Therefore, an efficient way to generate keys from biometrics image is also suggested in this paper. After key generation, the host image is first randomized followed by the embedding of the logo watermark in the singular values of the FrWPT sub-bands. The randomization process is performed with the help of non-linear chaotic map (NLCM) whose initial seed is obtained by the biometrics image of user/owner and acts as the key for proposed scheme. Apart from initial seed of NLCM, the transform orders of FrWPT also act as the keys and are obtained by the biometrics image of user/owner. Finally, the security, attack and comparative analysis demonstrate the better visual imperceptibility, resiliency and robustness of the proposed scheme against intentional or un-intentional variety of attacks. The main contribution of the proposed work can be summarized as follows.

- The main attraction of the proposed technique is the introduction of key concept in the SVD based watermarking system.
- The introduced keys play the vital role since none can extract the watermark without correct keys, even with the full knowledge of the embedding process.
- The employed keys are generated from the biometrics of user/owner and therefore, a generic key generation process is formulated.
- An authentication step based on image gradient is further casted during watermark extraction to strengthen the security.
- The proposed work also gives an efficient solution to meliorate ambiguous situations created by SVD in watermarking by verifying the singular vectors of the watermark using digital signature.
- Further, an efficient process to generate digital signature is also presented by exploiting the physical meaning and characteristics of singular vectors.

The rest of the paper is organized as follows. The description of used terminologies, i.e., fractional wavelet packet transform, non-linear chaotic map and singular value decomposition is explained in Section 2. In Section 3, the proposed biometric inspired watermarking scheme is explained followed by the detailed experimental results, attack analysis and ambiguity analysis in Section 4. The security and comparative analyses are further presented in the Sections 5 and 6, respectively. Finally, the concluding remarks are given in Section 7.

2. Mathematical preliminaries

In this section, the main terminologies are illustrated which are used in the proposed biometrics inspired watermarking technique to achieve the desired goal. These terminologies are as follows.

2.1. Fractional wavelet packet transform

The fractional wavelet packet transform (FrWPT) (Huang & Suter, 1998) of a 1D function $f(t)$ is given by

$$W_\alpha(u,s,\tau) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(t)K_\alpha(t,x)e^{-jux}\psi_{s,\tau}(x)dtdx, \tag{1}$$

where s, τ, α are the dilation (scale), translation (position) parameters and transform order, respectively. Further, $K_\alpha(t,x)$ is the transform kernel and is given by

$$K_\alpha(t,x) = C_\alpha e^{(i/2)(t^2+x^2)\cot\bar{\alpha}} \quad \text{where } C_\alpha = \frac{e^{i\bar{\alpha}/2}}{\sqrt{2\pi i\sin\bar{\alpha}}}. \tag{2}$$

It is clear that if $\bar{\alpha} = \alpha\pi/2, C_\alpha = \sqrt{\frac{1-i\cot\alpha}{2\pi}}$. Similarly, if $\sin\bar{\alpha} = 0$, by a limiting process the kernel reduces to a Dirac delta $[\delta(x \pm t)]$. From Eq. (1), it is clear that FrWPT is the realization of the wavelet packet transform in fractional Fourier domain. Fractional Fourier transform has a unique property of describing the information of spatial and frequency domain, due to the rotation of time–frequency plane over an arbitrary angle. In contrast, wavelet packet transform has a multiresolution property. A combination of these two results into FrWPT, that exhibits multiresolution property and describes the spatial as well as frequency domain information.

2.2. Non-linear chaotic map

A chaotic system is a deterministic non-linear system with pseudo stochastic property (Tao, Ruli, & Yixun, 2001). Due to its interesting properties like non-periodicity, unpredictability, initial parameter sensitivity and Gauss like statistical characteristics, many chaotic systems serve as the stochastic signal/sequence generator nowadays. In this work, we have used piecewise non-linear map in order to create digital sequence. Mathematically, a piecewise non-linear map (PWNLCM) $\mathcal{F}: I \to I$ where $I = [0,1]$ and denoting the length of the region, described as (Tao et al., 2001)

$$\mathcal{F}(x_{k+1}) = \begin{cases} \left(\frac{1}{I_{i+1}-I_i} + a_i\right)(x_k - a_i) - \frac{a_i}{I_{i+1}-I_i}(x_k - a_i)^2, & \text{if } x_k \in [I_i, I_{i+1}) \\ 0, & \text{if } x_k = 0.5 \\ \mathcal{F}(x_k - 0.5), & \text{if } x_k \in (0.5, 1] \end{cases} \tag{3}$$

where $x_k \in [0,1]$ and I_i is the sub-interval of [0,1] such that $0 = I_0 < I_1 < \cdots < I_i < \cdots < I_{n+1} = 0.5$ and $n \geqslant 2$. The parameter $a_i \in (-1,0) \cup (0,1)$ tune sequence in the ith interval such that $\sum_{i=0}^{n-1}(I_{i+1} - I_i)a_i = 0$. The interesting properties of the above mentioned map are summarized in Tao et al. (2001).