Optics and Lasers in Engineering ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Optics and Lasers in Engineering

journal homepage: www.elsevier.com/locate/optlaseng

Multiple color-image fusion and watermarking based on optical interference and wavelet transform

Muhammad Rafiq Abuturab

Department of Physics, Maulana Azad College of Engineering and Technology, Patna 801113, India

ARTICLE INFO

Article history:
Received 22 December 2015
Received in revised form
10 February 2016
Accepted 19 February 2016

Key words:
Multiple color-image fusion
Watermarking
Optical interference
Wavelet transform

ABSTRACT

A novel multiple color-image fusion and watermarking using optical interference and wavelet transform is proposed. In this method, each secret color image is encoded into three phase-only masks (POMs). One POM is constructed as user identity key and the other two POMs are generated as user identity key modulated by corresponding secret color image in gyrator transform domain without using any time-consuming iterative computations or post-processing of the POMs to remove inherent silhouette problem. The *R*, *G*, and *B* channels of different user identity keys POM are then individually multiplied to get three multiplex POMs, which are exploited as encrypted images. Similarly the *R*, *G*, and *B* channels of other two POMs are independently multiplied to obtain two sets of three multiplex POMs. The encrypted images are fused with gray-level cover image to produce the final encrypted image as watermarked image. The secret color images are shielded by encrypted images (which have no information about secret images) as well as cover image (which reveals no information about encrypted images). These two remarkable features of the proposed system drastically reduce the probability of the encrypted images to be searched and attacked. Each individual user has an identity key and two phase-only keys as three decryption keys besides transformation angles regarded as additional keys. Theoretical analysis and numerical simulation results validate the feasibility of the proposed method.

1. Introduction

With the rapid development of modern communication technology, both information security and intellectual property protection have become one of the most challenging issues. Recently, optical information security technology has attracted significant interest for its advantages as high-speed parallel processing of information with multiple degrees of freedom such as phase, amplitude, wavelength, polarization, and time. The secured data generation, transmission, storage and display of information/data are required to extend cryptographic technologies using optical methods. So optical based techniques for information security have been widely investigated to enhance the security of the cryptosystem [1–14]. Moreover, quantitative techniques have been developed for simultaneous compression and encryption of images [15,16]. Recently, the optical cryptosystem based on the diffractive imaging and phase-shifting interferometry techniques has been found venerable to chosen-plaintext and known-plaintext attacks, respectively [17,18].

Most of the DRPE-based optical systems involve recording of complex information, designing of conjugate phase mask, and precise alignment of optical elements. So, the optical setup of these systems is complicated. To overcome this problem, a novel architecture for optical image encryption based on interference has been proposed [19]. The original image is encoded into two phase-only masks (POMs) digitally and the encryption algorithm does not require iterative phase retrieval algorithm. Nevertheless, this system has an inherent silhouette problem due to the equipollent nature of the POMs. To deal with the silhouette problem, the original image is encoded into three POMs [20]. However, the silhouette information of original image can still be perceived, if the potential attackers possess two (first and third, or second and third) of the three POMs simultaneously to eliminate the modulation of random phase mask. The inevitable silhouette problem is resolved by encoding original image into three POMs, one with random phase distribution and the other two obtained analytically [21]. This approach has been later extended to the spiral phase distribution [22].

Recently, multiple-image encryption based on optical multiplexing techniques has received increasing interest in the field of optical information security, since it not only advances the encryption capacity but also facilitates the transmission and storage of the ciphertext [23–27]. One of the vital issues in multiple-image encryption is cross-talk noise due to recording multiple ciphertexts on a single medium, which degrades the quality of the

E-mail address: rafiq.abuturab@gmail.com

http://dx.doi.org/10.1016/j.optlaseng.2016.02.014
0143-8166/

Please cite this article as: Abuturab MR. Multiple color-image fusion and watermarking based on optical interference and wavelet transform. Opt Laser Eng (2016), http://dx.doi.org/10.1016/j.optlaseng.2016.02.014

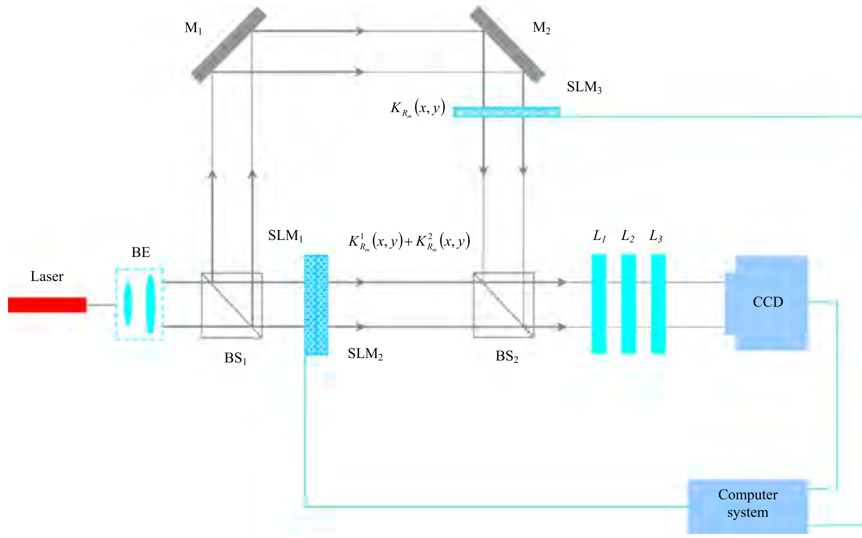

Fig. 1. Optoelectronic setup for proposed decryption system.

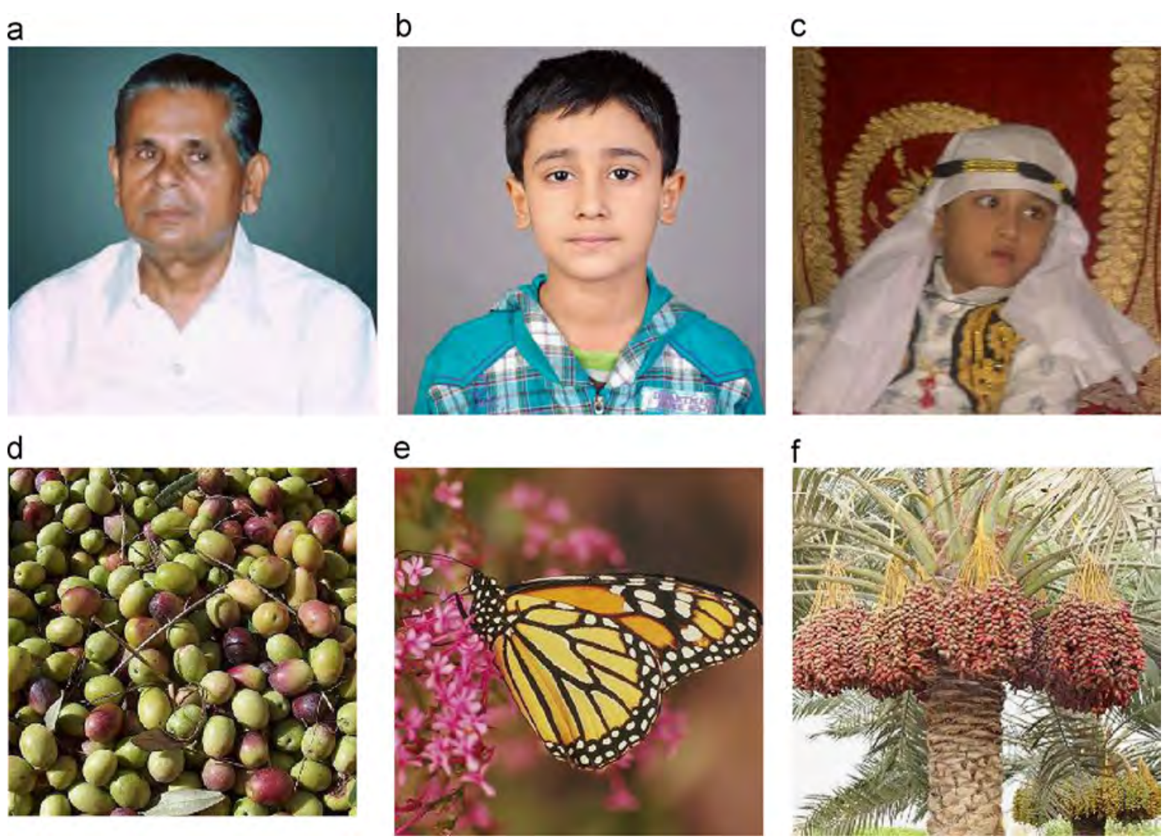

Fig. 2. User color images: (a) Father, (b) Ali, (c) Mahdi; secret color images: (d) Olive fruits for user image (a), (e) Fly for user image (b) and, (f) Date tree for user image (c).

decrypted images and consequently restricts the multiplexing capacity severely. To prevail over this issue, multiple-image security systems based on interference [28,29] as well as superposition [30,31] have been proposed.

The discrete wavelet transform (DWT) has been effectively applied in the signal processing, image encryption and compression in the network, multimedia and communications, because of time frequency localization, multi-scale and multi-resolution operations of the 2D data/image. Digital watermarking is an efficient approach for copyright protection, tamper detection, and content authentication of digital media. WT has also been found to be extremely useful in image watermarking. DWT-based image watermarking/hiding has been widely explored [32–34]. Generally, transform domain-based watermarking techniques provide only one spectrum plane for embedding the watermark. When the attacks dissolve the relationships between the original information and the predetermined set for the watermarking embedding, the watermark data can be easily removed. To solve this problem, a method for robust copyright protection using multiple ownership watermarks has been proposed [35]. In this scheme, multiple ownership watermarks are first recorded in the form of an elemental image array (EIA), simultaneously, and then the recorded

Please cite this article as: Abuturab MR. Multiple color-image fusion and watermarking based on optical interference and wavelet transform. Opt Laser Eng (2016), http://dx.doi.org/10.1016/j.optlaseng.2016.02.014