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Authentication of images for 3D cameras: Reversibly embedding information using intelligent approaches

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ABSTRACT

In this work, a reversible watermarking approach for authentication of 3D cameras based on computational intelligence is presented. Two intelligent techniques based on differential evolution (DE) and hybrid DE are employed to optimize the tradeoff between watermark imperceptibility and capacity. The proposed approach is suitable for images of 3D cameras. These cameras generally work on the concept of time-of-flight and not only produce the 2D image but also generate the corresponding depth map. In this approach, the depth map is considered as secret information and is hidden in the integer wavelet transform of the corresponding 2D image. The proposed technique is prospective for authenticating 3D camera images and allows the secure transmission of its depth map. It has the advantage of the lossless recovery of original 2D image as and when needed. The watermarking of the 2D images is based on integer wavelet transform and threshold optimization. The threshold map thus obtained using the intelligent optimization approaches is not only used for watermark embedding, but is also utilized for authentication purpose by correlating it with the corresponding 2D transformed image. Experiments conducted on images and depth maps obtained using 3D camera validate the proposed concept.

1. Introduction

3D information of an object is an important aspect of the devices used in controlling and routing applications. Web-conferencing, *3D* gaming, object tracking, automotive, mobile phones, robotics, and medical devices are potential areas, where fast and accurate *3D* information is required.

Time-of-flight (*TOF*) principle is used in *3D* cameras for computing the depth information of an object. The light source of these cameras emits light in the range of near infrared region. The reflected light from the surface of the target object is detected by a *3D* sensor of the camera. The light captured at the sensor of the camera is delayed in phase compared to the emitted light. The phase delay depends upon the distance of the object surface with the camera and is computed pixel-by-pixel (Hart et al., 2001). The resultant image is known as the depth map of the target object (Ringbeck, 2007). Fig. 1 shows the basic principle of TOF, while Fig. 2(a) shows the 2D images of a glass (Row 1), man (Row 2), face (Row 3), and toy (Row 4) images and Fig. 2(b) displays their corresponding depth maps.

Secret hiding of depth maps could be supportive in military and medical image processing. In case of medical applications, safe communication of medical images and videos between island and mainland hospitals for online discussion or tele-surgery is highly desirable (Takahashi, 2001). Therefore, if intelligently embedded and secured through secret keys, only an authorized person can extract the secret information.

Different kinds of watermarking schemes exist that are robust, fragile, and semi-fragile (Findik et al., 2010; Guo et al., 2011; Tsai et al., 2010). Guo et al. (2011) worked on the watermark algorithm in optical system based on fractional Fourier transform and random phase encoding. Findik et al. (2010) have developed robust watermarking technique for color images. In their work, they have used particle swarm optimization and *k* nearest neighbor tools in special domain to protect the intellectual property rights of the cover work. Tsai et al. (2010) developed a robust watermarking system based on support vector machine and α-trimmed mean operator.

There is another category of watermarking, which is gaining significant importance, called reversible watermarking. Reversible watermarking is considered as a prospective technique for the secure transmission of digital content and reverting back the original image (Arsalan et al., 2011; Zielinski and Laur, 2006). Xuan et al. (2005) reported their work based on reversible embedding of the watermark bits into the middle and high frequency integer wavelet coefficients. In the work presented by Lee et al. (2007), reversible

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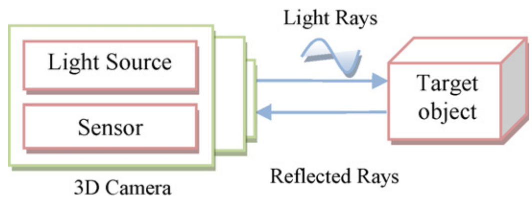

Fig. 1. Basic principle of *TOF*.

watermarking has been performed on integer-to-integer wavelet transform domain using Cohen–Daubechies–Feauveau (*CDF*) filter. Tian (2003) has applied difference expansion technique to hide data on the images, reversibly. Khan et al. (2008) have presented their work on embedding the depth map as a watermark in integer-to-integer wavelet transform domain using Variable Threshold technique. Chen and Tsai (2011) have reported adaptive block size reversible watermarking scheme. Ali and Khan (2009) have reported another technique for reversible watermarking using *3D* images. In their work, they have adaptively computed the threshold matrix for the image. Once a threshold matrix is computed, it is used to embed the depth map in its corresponding *2D* image.

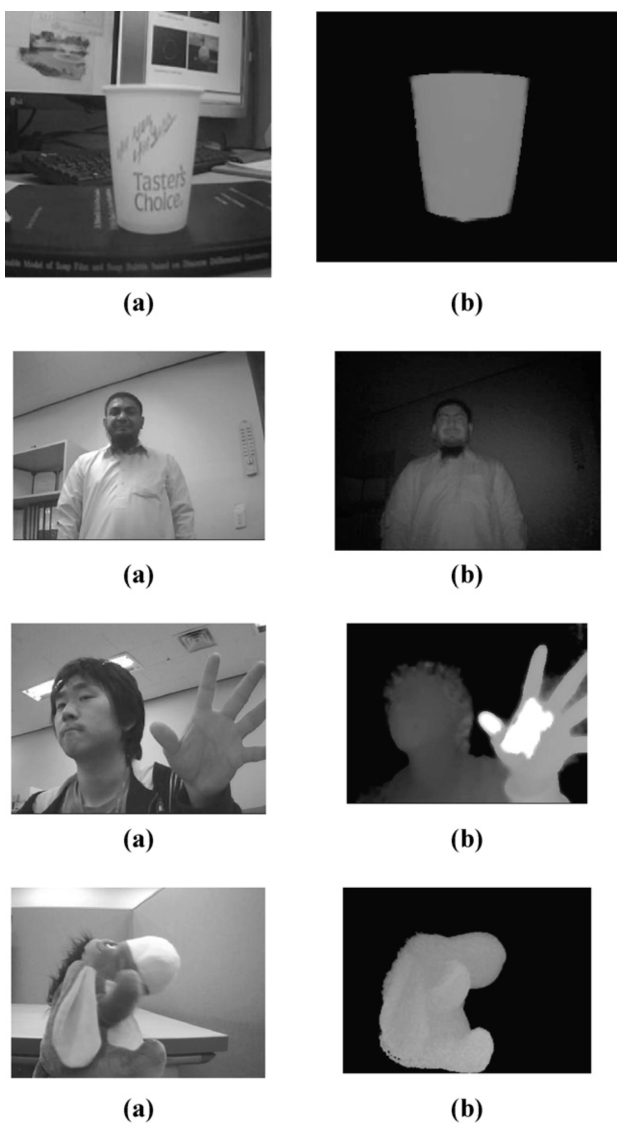

Fig. 2. Column (a) 2D images, Column (b) depth map images of Column (a). Row (1) glass image, Row (2) man image, Row (3) face image, Row (4) toy image.

However, still researchers are investigating ways to improve the capacity of reversible watermarking approaches.

Authentication of the digital content is an important issue due to its frequent manipulation and easy distribution over the communication channel (Chamlawi and Khan, 2010). In the work of Aslantas et al. (2009), the performance of fragile watermarking based on discrete cosine transform has been improved by using intelligent optimization algorithms. When an image, after embedding process, is transformed from frequency domain to spatial domain, undergoes some round off errors problem. Aslantas et al. (2009) have used intelligent optimization algorithm to correct these errors. Chang et al. (2011) have proposed a secure watermarking technique. In their approach, they have developed a hybrid scheme by combining two-pass logistic map with hamming code, for image protection and tamper detection. Tsai et al. (2010) have reported a technique based on α trimmed mean operator and support vector machine (*SVM*). In this approach, *SVM* is trained to memorize relationship between the watermark and the image-dependent watermark. The trained *SVM* is used to recover the watermark and then the recovered watermark is compared with the original watermark to authenticate the ownership.

In this work, we have developed an authentication method that enables a *3D* camera in secretly hiding the depth map of an object in its corresponding *2D* image. Thus, not only the depth map can be secretly communicated but the corresponding 2D image can also be authenticated. It is a block-based technique in integer discrete wavelet transform (*IDWT*) domain. After taking *IDWT* of an image, the image is divided into four sub-bands, namely approximation (*LL*), horizontal (*LH*), vertical (*HL*), and diagonal (*HH*). *IDWT* maps integers to integers and has been adopted by *JPEG2000*. In the first step, a threshold matrix (*Tmap*) is generated using intelligent optimization approaches in such a way that after watermarking, it should provide good imperceptibility against a desired payload without generating underflow/overflow. This *Tmap* is used in the watermark embedding step. At the receiving side, the depth map can be extracted from the *2D* image and the *2D* image can be authenticated. Additionally, the *2D* cover image can be restored to its original form by an authorized person. The watermarking technique that we are employing here is a fragile reversible watermarking.

The rest of the paper is organized as follows: Section 2 discusses in detail the proposed reversible watermarking approaches. Section 3 presents experimental results and discussion, while Section 4 provides conclusions.

2. Proposed reversible watermarking of depth map

In the proposed method, once the depth map has been obtained through *3D* Camera, Huffman compression is applied to remove the redundancy. Encryption of the depth map is then performed using *RSA* algorithm (Rivest et al., 1978), whereby the security of the system is further enhanced. After compression and encryption, the depth map is ready to be embedded in the *2D* image with the intention that it could be extracted accurately as and when needed, but only by an authorized person. For watermark embedding procedure, *Tmap* is required.

In the last two decades, use of evolutionary algorithms (*EAs*) in various fields of science and engineering has been increased extensively for solving constrained optimization problems (Afridi et al., 2012; Naveed and Khan, 2012). These algorithms work on the principle of natural selection and recombination to search for possible solutions under certain fitness criterion. Examples of *EAs* are genetic algorithm, genetic programming, differential evolution, etc. Here, we are also dealing with a constraint optimization problem, whereby the tradeoff between watermark