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Forward and Inverse Reversible De-Identification Method for Lossless Compressed Images to Make the System Reversible

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Abstract: ***Video surveillance cameras are becoming ubiquitous in many developed countries. This has raised several privacy concerns which have pushed policy makers to regulate their use. One approach to provide privacy is to obfuscate sensitive regions within an image/video which prevents the identification of the persons being captured. The authors have proposed an irreversible obfuscation method which however, prevents the use of the captured videos from aiding criminal investigation or to be used as evidence in court. De-Identification is a process which can be used to ensure privacy by concealing the identity of in dividuals captured by video surveillance systems. One important challenge is to make the obfuscation process reversible so that the original image/video can be recovered by persons in possession of the right security credentials. This work presents a novel Reversible De-Identification method that can be used in conjunction with any obfuscation process. The residual information needed to reverse the obfuscation process is compressed, authenticated, encrypted and embedded within the obfuscated image using a two-level Reversible Watermarking scheme. The proposed method ensures an overall single-pass embedding capacity of1.25 bpp, where 99.8% of the images considered required less than 0.8 bpp while none of them required more than1.1 bpp. Experimental results further demonstrate that the proposed method managed to recover and authenticate allimages considered.***

I. INTRODUCTION

Reversible data hiding (RDH) aims to embed secret message into a cover image by slightly modifying its pixel values, and, unlike conventional data hiding, the embedded message as well as the cover image should be completely recovered from the marked content. RDH is a special type of information hiding and its feasibility is mainly due to the lossless compressibility of natural images. The reversibility in RDH is quite desirable and helpful in some practical applications such as medical image processing, multimedia archive management, image trans- coding, and video error-concealment coding, etc. Generally, the performance of a RDH scheme is evaluated by the capacity-distortion behavior. For a required embedding capacity (EC), to obtain a good marked image quality, one expects to reduce the embedding distortion as much as possible.

Many RDH methods have been proposed so far, e.g., the methods based on lossless compression, difference expansion, histogram modification], prediction-error expansion, and integer transform, etc. Among them, the histogram-based ones have attracted much attention. The histogram-based methods modify the histogram in such a way that certain bins are shifted to create vacant space while some other bins are utilized to carry data by filling the vacant space. This type of methods can well control the embedding distortion and provide a sufficient EC. The first histogram-based RDH method is the one proposed. This method uses peak and minimum points of the pixel-intensity-histogram to embed data. It changes each pixel value at most by 1, and thus a good marked image quality can be obtained. However, its EC is quite low and this method does not work well if the cover image has a flat histogram.

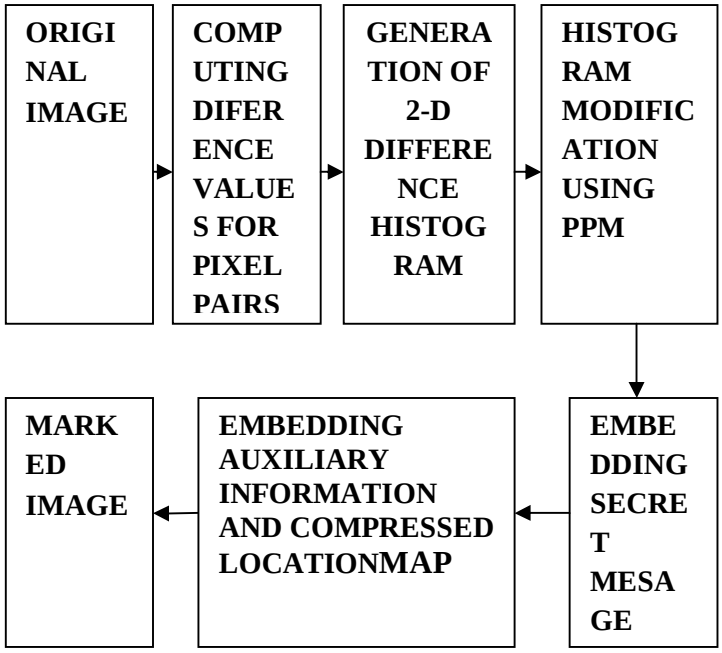
II. RDH SCHEME

In this paper, we propose a new reversible data embedding technique, which can embed a large amount of data (5–80 kb for a 512×512 8 grayscale image) while keeping a very high visual quality for all natural images, specifically, the PSNR of the marked image versus the original image is guaranteed to be higher than 48 dB. It utilizes the zero or the minimum point of the histogram (defined below) and slightly modifies the pixel grayscale values to embed data. This technique can be applied to virtually all types of images. Up to now, it has been successfully tested on different types of images, including some commonly used images, medical images, texture images, aerial images, and all of the 1096 images in Corel DRAW database. The computation of our proposed technique is quite simple and the execution time is rather short. Although the proposed lossless data hiding technique is

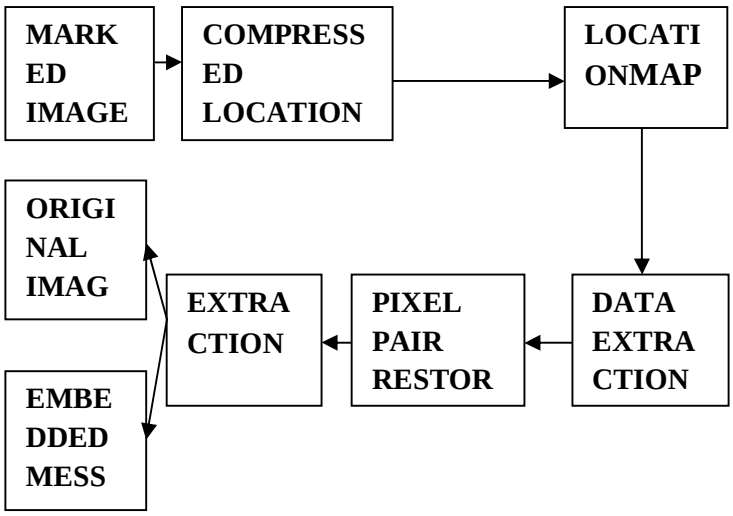
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applied to still images, it is also applicable to videos which consist of a sequence of images. To the best of our knowledge, the only proposed reversible data hiding technique for binary images is PWLC (Pair-Wise Logical Computation). However, it seems that sometimes PWLC does not correctly extract the hidden data, and fails to recover perfectly the original cover image.

A. Encryption



B. Decryption: decompress



III. FORWARD REVERSIBLE DE-IDENTIFICATION

A. Face Obfuscation

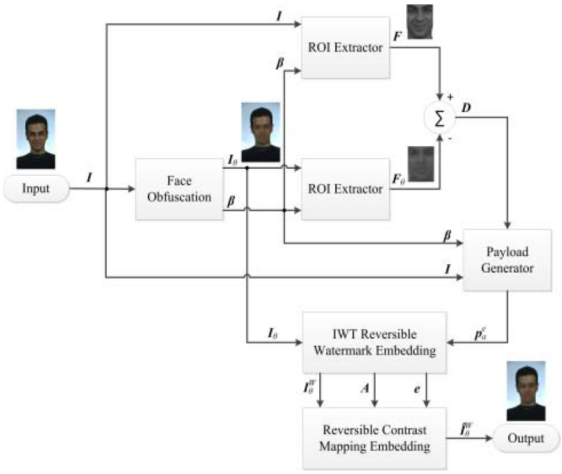
The Face Obfuscation process receives the original image I and detects the face region and eye locations using the ground truth information available in the color FERET dataset. This can be automated using the face detector in [12] and the eye detector in [13] which ensure high accuracies. However, the main contribution of this work is to present a Reversible De -Identification method which is independent from the obfuscation process. Thus, the automation of the face and eye detectors is not in the scope of this work. The upper left and bottom right coordinates of the face region are included in the bounding box β and use dt o extract the face which is aligned using affine transformations [14]. The aligned face image F is then concealed using the k-same algorithm, which

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computes the average face derived over the *k* closest aligned faces in Eigen-space, to generate the obfuscated aligned face image $F\Theta$. More information on the *k*-same algorithm can be found in [2]. The obfuscated face image $F\Theta$ is then realigne dto match the orientation of the original face image *F*using affine transformations and then overwrites the face region in the original image *I* to derive the obfuscated image $I\Theta$.

B. ROI Extraction

The ROI Extraction process is a simple algorithm which employs the bounding box coordinates β to identify the region to be cropped from the input image *I*(or $I\Theta$). The cropped sub-image is then stored in the face image *F*(or obfuscated face image $F\Theta$).



C. Payload Generator

The Payload Generator Process receives the difference image ***D*** which is compressed using the predictive coding method presented in [15] followed by the Deflate algorithm [16]. The original image ***I*** is authenticated using SHA-1 which generates a 20-Byte*Hash*. The *Hash* will be used by the Inverse Reversible De-Identification process to ensure that it recovers the original image ***I***, and is thus appended to the *Payload*. The bounding box coordinates $\boldsymbol{\beta}$ are also required at the
receiver to identify the face region and are therefore included as information within the header.

D. ROI Extraction

The ROI Extraction process is a simple algorithm which employs the bounding box coordinates $\boldsymbol{\beta}$ to identify the region to be cropped from the input image ***I***(or $\boldsymbol{I\Theta}$). The cropped sub-image is then stored in the face image ***F*** (or obfuscated face image $\boldsymbol{F\Theta}$).

E. Payload Generator

The Payload Generator Process receives the difference image ***D*** which is compressed using the predictive coding method presented in [15] followed by the Deflate algorithm [16]. The original image ***I*** is authenticated using SHA-1 which generates a 20-Byte*Hash*. The *Hash* will be used by the Inverse Reversible De-Identification process.

IV. INVERSE REVERSIBLE DE-IDENTIFICATION

A. Reversible Contrast Mapping Extraction

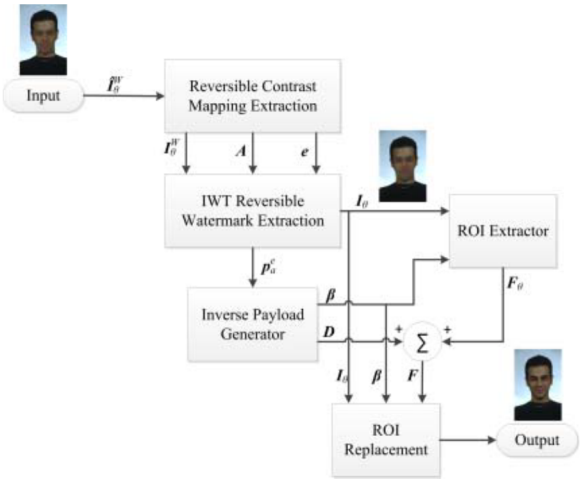
The Reversible Contrast Mapping Extraction processreceives the image $\hat{\mathbf{I}}\theta$
W and recovers $\mathbf{I}\theta$W and **r**. The information bit can be extracted from the LSB of y' when
the LSB of x' is '1'. However, in the event when the LSBo fx' is '0', both LSBs of x' and y' are forced to be odd and condition (9) is checked. If the condition is satisfied it then represents an odd pixel pair while if it does not it indicates that y = y' and the original LSB value of x is extracted from the bit stream. More information about this is available in [21]. The auxiliary information **A** and residual bit stream **e** are then extracted from the packet **r**.

B. IWT Reversible Watermarking Extraction

The IWT Reversible Watermarking Extraction reverses the IWT Reversible Watermarking Embedding process and extracts the

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payload information **p**ea and the original
obfuscated image **I**Θ. It must be noted here that initially ,the decoder has no knowledge about the number of decompositions employed N dec and the threshold values **T**.
The decoder thus assumes that a single decomposition is employed and that the threshold values are set to zero. These values are then updated once they are extracted from the header information of **s**. It is important that the encoder does the same thing during embedding in order to ensure synchronization between the encoder and decoder.



C. ROI Replacement
The *ROI Replacement* process replaces the region marked by the bounding box ***β*** with the recovered face image ***F***. The image ***I****re*can be authenticated by comparing the hash derived by computing the *SHA-1* on ***I*** *rec*to the *Hash* value present in the tail of the packet ***pa***.

V. CONCLUSION

In this paper, we presented a novel RDH scheme by using a two-dimensional difference-histogram according to a specifically designed DPM. In addition, a pixel-pair-selection strategy is also proposed to further enhance the embedding performance. This work is the first attempt to employ higher dimensional histogram to design RDH. Compared with the previously introduced one-dimensional histogram based methods, our approach can exploit the image redundancy better and achieve an improved performance. However, since only one pixel ofa pixel-pair is allowed to be modified by 1 in value, our EC is low. This issue should be investigated in the future. Moreover ,utilizing more suitable two-dimensional histogram and designing more meaningful DPM (e.g., in an image dependent way) to achieve the best embedding performance is also a valuable problem.

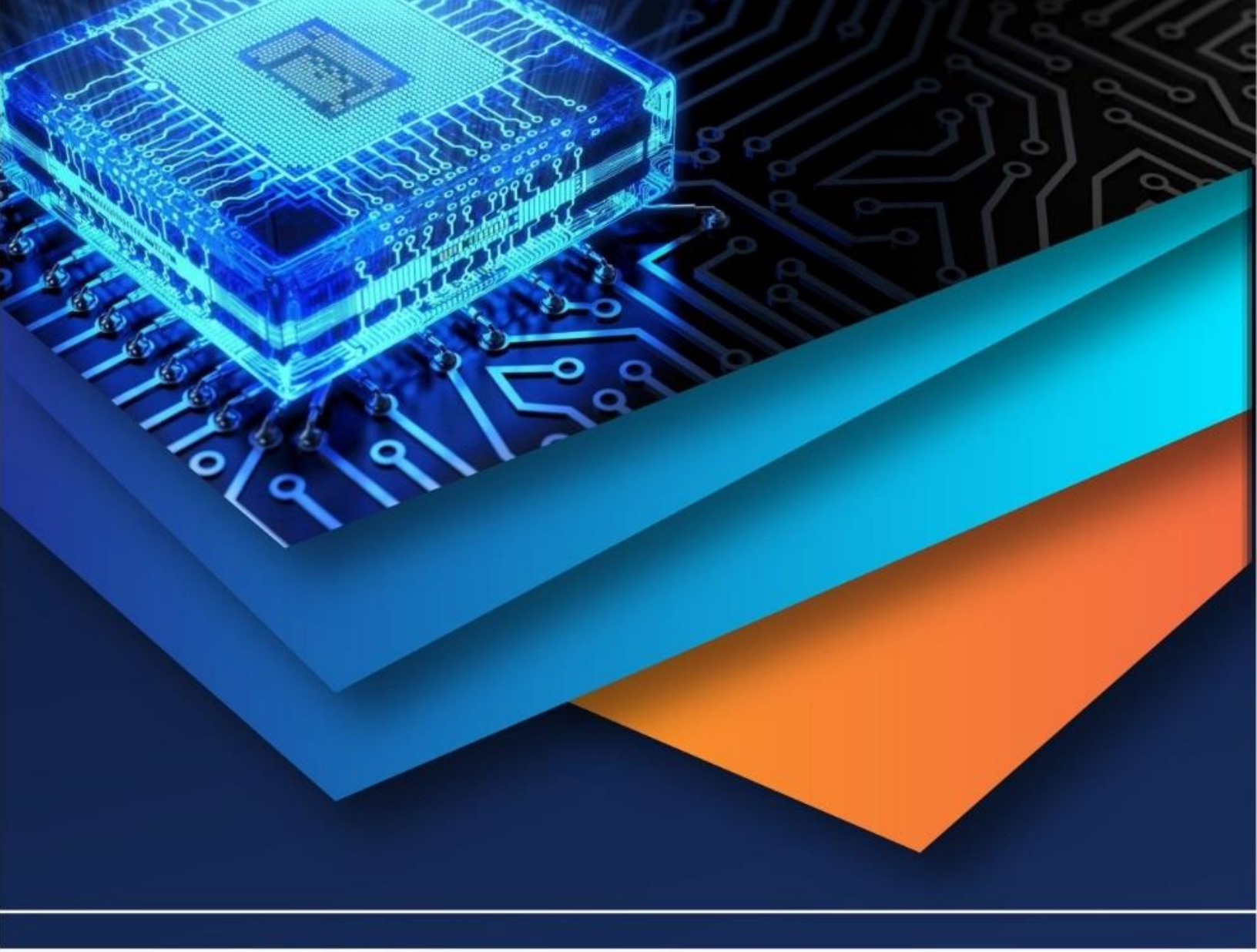
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