Reversible and Tunable Scrambling-Embedding Method

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Abstract—This paper proposes a reversible unified method to scramble an image and embed information into it using row and column rotation methods. Each row (column) is divided into groups and rotated to the left (bottom) to distort the image. Unique states are derived during the rotation process and utilized to embed external information. In the decoding process, the pixel correlations in the vertical and horizontal directions are exploited to reconstruct the original image and extract the embedded information. The proposed method is able to control the output image quality to achieve its intended distortion using the control parameters. Experiments are conducted to verify the basic performance of the proposed method. Our previously proposed method is adopted to further improve the proposed method in terms of payload and quality degradation of the output image. It is verified that the original image can be perfectly reconstructed and the proposed method itself is able to achieve an average effective payload up to ~9015.0 bits. SSIM and PSNR values are measured to determine the range of achievable distortion using different parameters.

I. INTRODUCTION

Nowadays, almost all of the contents, especially images, are stored in digital format and readily shared across a wide geographical area through the Internet. As such, there is a tremendous need to efficiently administrate and protect these contents from being misused by a third party. For that, scrambling technology is invented to obscure the perceptual meaning of a multimedia content, protecting the original content from unauthorized viewing. On the other hand, data embedding is proposed to insert external information into the host content. The information embedded varies depending on the purposes of the application, e.g., visible watermark to render ownership, description or hyperlinking to enrich the content, etc. Nonetheless, in these two seemingly different disciplines, reversibility is one of the attractive properties shared by the two, which refers to the ability to losslessly reconstruct the original content by means of reversing the embedding or scrambling process.

Reversible data embedding can be divided into three main categories, namely: (a) histogram shifting; (b) expansion-based, (c) compress-and-append method. Ni et al. proposed histogram shifting method which embeds information using the peak and empty bins in the image histogram [1]. Huang et al. improved the payload (hereinafter referred to the number of bits embeddable into the content) of [1] by using quadtree decomposition to divide the image into variable block sizes [2]. For expansion based technique, Tian et al. proposed to embed data using the difference between two adjacent pixel values [3]. Thodi et al. then proposed to embed data in the prediction errors [4]. On the other hand, Fridrich et al. proposed a general framework for compress-and-append in all digital format to achieve reversible data embedding [5]. Using a similar framework, Celik et al. proposed to quantize the host signal and compress its residuals (i.e., quantization errors) to vacate space for data embedding [6]. Then, the compressed residuals and payload are appended to the host signal using the generalized LSB modification method. This method also provides scalability in terms of distortion and payload. However, the aforementioned reversible data embedding methods aim to embed data while maintaining high image quality.

On the other hand, Hu et al. proposed to scramble an image using simple XOR operation in row and column manners [7]. This method selects row(s) using a key and XOR other rows with the selected row(s) to distort the image. Meanwhile, Wong et al. proposed an unified constructive permutation function to scramble the image [8]. This method divides the pixels of a row in small groups and permutes the pixels within each group. The permuted groups are recursively combined in an alternate order to achieve distortion. Wu et al. proposed to generate a sudoku matrix which will be utilized to modify the pixel values and locations in the image to achieve distortion [9].

Traditionally, scrambling and data embedding are studied independently. Hence, all the aforementioned methods [1], [2], [3], [4], [5], [6], [7], [8], [9] are meant for single purpose, i.e., either data embedding or scrambling only. Recently, research on the unification of both disciplines is gaining much attention from the society. Integration of these two disciplines enables more diverse usability in a system because it can serve multiple purposes simultaneously. For example, [10] illustrated a scenario where a lower rank officer (e.g., secretary) can administrate the scrambled-embedded images by referring to the embedded metadata without knowing the actual perceptual meaning of the images. In addition, Kundur et al. proposed to insert fingerprint into the video to trace illegal distribution while encryption is applied prior to the transmission to avoid unauthorized viewing [11]. Ong et al. proposed to scramble an image using histogram association mapping based data embedding method [12]. The output quality can be controlled to serve users of different access levels. This controllability is particularly useful for image warehouse because multiple versions (i.e., different distortions) of the image can be generated using the original image stored in the database by simply tuning a control parameter. Nevertheless, the output images from [12] suffer from unpleasant artifacts such as blockiness and edginess because they are implemented in a fixed block.