Signal Processing 108 (2015) 376–388

Contents lists available at ScienceDirect

Signal Processing

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

High capacity reversible data hiding scheme based on residual histogram shifting for block truncation coding

I-Cheng Chang [a], Yu-Chen Hu [b,*], Wu-Lin Chen [b], Chun-Chi Lo [c]

[a] Department of Computer Science and Information Engineering, National Dong Hwa University, 1, Sec. 2, Da-Hsueh Rd., Shou-Feng, Hualien 97401, Taiwan, ROC
[b] Department of Computer Science and Information Management, Providence University, 200 Chung Chi Rd., Taichung 43301, Taiwan, ROC
[c] Department of Computer Science and Information Engineering, Providence University, 200 Chung Chi Rd., Taichung 43301, Taiwan, ROC

ARTICLE INFO

Article history:
Received 9 January 2014
Received in revised form
29 July 2014
Accepted 29 September 2014
Available online 8 October 2014

Keywords:
Reversible data hiding
Block truncation coding
Histogram shifting
Predictive coding

ABSTRACT

A reversible data hiding scheme based on residual histogram shifting for the compressed images of block truncation coding (BTC) is proposed. This scheme employs an iterative approach to embed the secret data into the compressed codes of BTC. In each round, the quantization levels are processed by the block-based prediction technique to generate the residual values. Then, the residual values are used to embed the secret data. Multiple rounds of the data embedding process can be executed to increase the hiding capacity of the proposed scheme. Experimental results reveal that the proposed scheme provides good image qualities of the embedded images. In addition, the hiding capacity of the proposed scheme is greater than that of the comparative scheme. Furthermore, the embedded compressed codes still follow the standard format of BTC after the proposed data embedding procedure is executed.

1. Introduction

Recently, the research towards data hiding [1] becomes more and more popular. Generally, data hiding schemes can be classified as spatial domain schemes, frequency domain schemes, and compressed domain schemes. The spatial domain schemes and the frequency domain data hiding schemes embed secret data into the pixels and the transformed coefficients of digital images, respectively. The compressed domain data hiding schemes embed the secret data into the compressed codes of digital images. Typically, the hiding capacity of one compressed domain data hiding scheme is less those of the spatial domain and frequency domain data hiding schemes.

According to the reversibility of embedded media, data hiding schemes can be classified into two categories: irreversible data hiding schemes [1–4] and reversible data hiding schemes [5–21]. In the irreversible data hiding schemes, secret data is embedded into the cover media to generate the stego-media. Then, secret data can be extracted when it is needed by executing the secret extraction procedure. However, the original cover media cannot be recovered back to their original forms. On the contrary, the reversible data hiding schemes can extract the secret data and recover the stego-media back to the original media if needed. That is why the reversible data hiding schemes are also called the lossless data hiding schemes. In general, the hiding capacity of one reversible data hiding scheme is less that of the irreversible data hiding scheme. Nevertheless, the image quality of embedded images for the reversible data hiding scheme is better than that for the irreversible data hiding scheme.

Basically, the reversible data hiding schemes [5] can be divided into two main approaches. They are the histogram

* Corresponding author. Tel.: +886 4 26328001x18112; fax: +886 4 26324045.
E-mail addresses: icchang@mail.ndhu.edu.tw (I.-C. Chang), ychu@pu.edu.tw (Y.-C. Hu), wlchen@pu.edu.tw (W.-L. Chen), cclo@pu.edu.tw (C.-C. Lo).

http://dx.doi.org/10.1016/j.sigpro.2014.09.036
0165-1684/

shifting approach [6–10] and the difference expansion approach [11–14]. The reversible data hiding scheme based on histogram shifting (HS) [6] was proposed by Ni et al. In the HS scheme, the histograms of the pixels in the cover image are explored, and the pairs of the peak and zero points are searched. The pixels between the peak and zero points are modified in the data embedding process. Each pixel in the peak points is used to embed 1-bit secret data. The others are modified and no secret data are embedded. In the HS scheme, the number of pixels in the peak points is the maximal hiding capacity for the secret data to be embedded. Multiple pairs of the peak and zero points can be used in the HS scheme to increase the hiding capacity.

To improve the hiding capacity of the histogram shifting technique [6], Tsai et al. proposed an improved data hiding scheme based on residual histogram shifting (RHS) [7]. In the RHS scheme, the cover image is divided into non-overlapping image blocks. The center pixel in each image block is selected as the basic pixel for linear prediction. Each pixel in the block is processed by using the linear prediction technique to generate the residual values. The residual histogram of the cover image is employed to embed the secret data. Similarly, multiple pairs of the peak and zero points can be used in the RHS scheme to increase the hiding capacity. Some improved histogram shifting methods had also been proposed [8–10]. The main goal of these methods is to increase the number of the peak values within the histogram of the input images.

The difference expansion (DE) scheme for reversible data hiding was proposed by Tian [11]. In the DE scheme, the redundancy of the pixels is explored, and each pair of two neighboring pixels is used to embed at most 1-bit secret data. The difference and average value of two neighboring pixels in each pair are computed. The secret data to be embedded is appended to the difference value represented as a binary number. In other words, the difference value is first multiplied by 2. Then, the sum of the difference value and 1-bit secret data is calculated. The calculated result is stored in the modified difference value. Two modified neighboring pixels are replaced by the summation and subtraction of the average values. In the DE scheme, the overflow and underflow problems may happen when the modified pixels are greater than 255 and less than 0, respectively. Therefore, a location map is required in the DE scheme so that the data reversibility can be kept. To improve the performance of the difference expansion technique, some reversible data hiding schemes had been proposed [12–14].

From the literature, most of the reversible data hiding schemes [5—14] worked on the raw images. Several compressed-domain reversible data hiding schemes had also been proposed [15–21]. Some reversible data hiding schemes for the compressed images of the vector quantization scheme (VQ) had been proposed [15–18]. Chang et al. proposed the lossless data hiding scheme [15] for VQ compressed images. In this scheme, a VQ codebook, which had already been clustered into three groups, was adopted to achieve secret concealment and data recovery. In order to embed more secret data, the concepts of frequency clustering and trio extension were also introduced. A novel reversible data hiding scheme [16] for VQ-compressed images had been proposed in 2009. In this scheme, the index table is further compressed by the local adaptive coding scheme. Secret data is embedded into VQ indices in an index table during the post compression process. Tsai proposed the reversible data hiding scheme [17] for the compressed images of the vector quantization technique. In this scheme, the histogram shifting technique is employed to embed the secret data into the histogram of the indices of the compressed image blocks. In addition, an efficient reversible data hiding for VQ-compressed images based on index mapping mechanism had been proposed [18].

Some reversible data hiding schemes [19–21] for the compressed images of the block truncation coding scheme (BTC) [22–24] had been proposed. Chang et al. proposed the reversible data hiding scheme for BTC-compressed color images in 2008 [19]. In this scheme, a genetic algorithm is applied to find an approximate optimal common bit map to replace the original three. Then, the secret data are embedded in the common bit map and the quantization levels of each block by using the properties of side matching and the order of these quantization levels to achieve reversibility. Chang et al. proposed the reversible data hiding scheme for BTC-compressed grayscale images [20]. The properties of side matching and the order of these quantization levels are explored to embed the secret data into the compressed codes. The embedded results of these two schemes [19,20] did not satisfy the compressed format of BTC.

In addition, Lo et al. proposed the reversible data hiding scheme [21] for the compressed images of block truncation coding. The histogram shifting technique [6] was employed in the scheme to embed the secret data into the quantization levels of the compressed codes. After the data embedding procedure is executed, the embedded compressed codes still follow the standard format of BTC. Multiple pairs of the peak and zero points can be used in the scheme to increase the hiding capacity. However, the limited hiding capacity is its main weakness.

In this paper, we design a high capacity reversible data hiding scheme for BTC-compressed images to improve the hiding capacity of the BTC-based reversible data hiding scheme [21]. The proposed scheme intends to embed the secret data into the quantization levels of the compressed image blocks. Our earlier published technique, the RHS scheme [7], motivates us to design the secret data embedding process. The best basic element for block-based linear interpolation will be exploited in the proposed scheme. The embedded results will still satisfy the compressed format of the BTC scheme. The rest of this paper is organized as follows. We will briefly review the block truncation coding scheme in Section 2. Section 3 will present the proposed scheme. The experimental results will be discussed in Section 4. Finally, some discussions and conclusions will be given in Section 5.

2. Review on block truncation coding

The block truncation coding scheme (BTC) [22] is a simple and low cost image coding method for digital