

Reversible data hiding using local edge sensing prediction methods and adaptive thresholds

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ABSTRACT

This paper proposes an improved reversible data hiding technique by utilizing Lukac, Feng, and Fan's expanding method. The scheme uses standard deviation to analyze the complexity of an image to determine the prediction method. The proposed scheme applies two thresholds to control the hiding capacity. The first threshold is used to decide which equation is better to calculate the prediction value. The second threshold is used to estimate the cover pixel is embeddable. The threshold values greatly affect the capacity and image quality of the stego image. Hence this paper develops a systematic scheme to determine the thresholds to obtain more accurate prediction results. A shifting-based histogram technique is then built from the prediction error values and secret message is embedded in pixels with low predicted error value. The experimental results demonstrate that a high image quality is achieved. From the experimental results, we can see that the image quality of the proposed scheme is better than that of Lukac's or expanded Lukac's method. Especially when the hiding capacity is set to be low, the PSNR value of the proposed is 5 db more than that of the other two methods. The smooth images, such as Lena, Goldhill, Living room images have the smallest difference in PSNR among the algorithms, while the complex images, such as Mandrill, Peppers, Barbara, Boat, and Pirate images show improved PSNR values in the proposed embedding method compared to the other two algorithms. On average, the proposed method can improve 2 dB than Feng's method. Specially, for complex images such as Mandrill, the proposed scheme can obtain more than 3 dB gain. The application of the proposed method to complex images provides improved noise and embeddable capacity properties.

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1. Introduction

Data hiding refers to embedding hidden information into cover images where the embedded information is

imperceptible to others. Traditional data hiding techniques will induce some permanent destruction of the host image after embedding the hidden information [8]. Therefore, several articles have investigated reversible data hiding (RDH) in order to restore the stego image to the cover image without any loss.

The reversible data hiding technique, also known as the lossless data hiding technique, can recover the original image without any loss in the original image after extracting the hidden information. The technique can be used in various fields, such as medicine, the military, fine arts, and so on [10].

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Improving the embedding capacity and image quality represents a challenge for researchers interested in RDH.

Recently, several RDH methods have been developed. Tian (2003) presented the difference expansion technique [11]. The method discussed by Tian is based on expanding the difference between a pair of neighboring pixels and embedding hidden information. Alattar (2004) expanded Tian's method using the difference expansion of vectors to increase embedding capacity [1]. Tsai et al. (2005) utilized pair-wise logical computation (PWLC) for binary images, where the concept of the exclusive- or logical operation is adopted to achieve data hiding [12]. Ni et al. (2006) developed a RDH method based on image histogram modification [8]. Yang and Tsai (2009) presented an interleaving images approach based on shifting-based histograms [13]. Their methods are able to enhance accurate prediction and image quality.

Feng and Fan (2012) improved Lukac's method based on shifting-based histograms, and the modified method provides high embedding capacity [3]. Hong (2012) improved Tai's method for adaptive prediction of error values and applied a dual binary tree (DBT) to enhance embedded space capacity through a shifting-based histogram [5]. Yang et al. (2013) presented an RDH algorithm based on gradient-based edge direction prediction (GEDP). The method uses difference expansion to embed hidden information with high image quality [9]. Zhang (2013) proposed optimal value transfer to modify prediction error and the method can produce an acceptable embedding capacity [14]. Li et al. (2013) proposed a reversible hiding scheme for color image. They use different color channels to compute the prediction value and to embed secret message [6]. The proposed scheme can effectively enhance the prediction accuracy and embedding capacity.

The previously mentioned methods can be classified into two types:

1. Difference expansion: the techniques use the difference between original pixels (or coefficients) and prediction value to embed message, such as the work done by Tian (2003), Alattar (2004), Yang (2013), Zhang (2013), and Li (2013).
2. Histogram shifting: the techniques use pixels or prediction error to analyze a histogram and embed secret message in peak values, such as the work done by

Ni (2006), Yang (2009), Feng (2012), Fujiyoshi (2012) [4], and Hong (2012).

How to calculate the prediction value is an important issue in RDH. An image has low distortion when the difference between the pixel and the prediction value is low. In the previous research, difference values are calculated by the mean or the difference between a pixel pair. In order to reduce the prediction difference, predictive methods are utilized on neighboring pixels using means or weighting concepts to improve accurate prediction values. For example, Lukac et al. used edge sensing prediction to calculate the weight of neighboring pixels. Feng and Fan expanded Lukac's concept to increase the range of edge sensing prediction pixels.

Feng and Fan's method can effectively enhance accurate predictions when the image has complex characteristics. However, the method is not effective when the image is smooth. Therefore, this paper presents an improvement to Feng and Fan's method through analyzing the standard deviation per block and using different prediction schemes for each pixel block. The proposed scheme uses two thresholds to determine whether the pixel is embeddable. In order to reduce the artificial influence on threshold setting, this research utilizes an adaptive method for setting thresholds. Finally, the proposed scheme calculates prediction error and embeds secret message by using histogram-shift algorithm.

This paper is organized as follows. Section 2 presents some related works, such as Ni's histogram-shift technique (Section 2.2), Lukac's edge sensing prediction method (Section 2.3), and Feng and Fan's method (Section 2.4). Section 3 describes the research procedures. Section 4 then discusses the adaptive threshold setting strategy (Section 4.1) and experimental results apply to four complex images (Section 4.2). Finally, conclusions are presented in Section 5.

2. Related works

2.1. Interleaved images

Bayer et al. presented the color filter array (CFA) approach in 1976. The method assumes that a matrix where only one color channel recorded in the array and the RGB color matrix are associated as shown in Fig. 1(a). In 2004, Lukac et al. transformed the original CFA approach into an interleaved color matrix shown in Fig. 1(b) [7]. In 2009, Yang and Tsai [13]

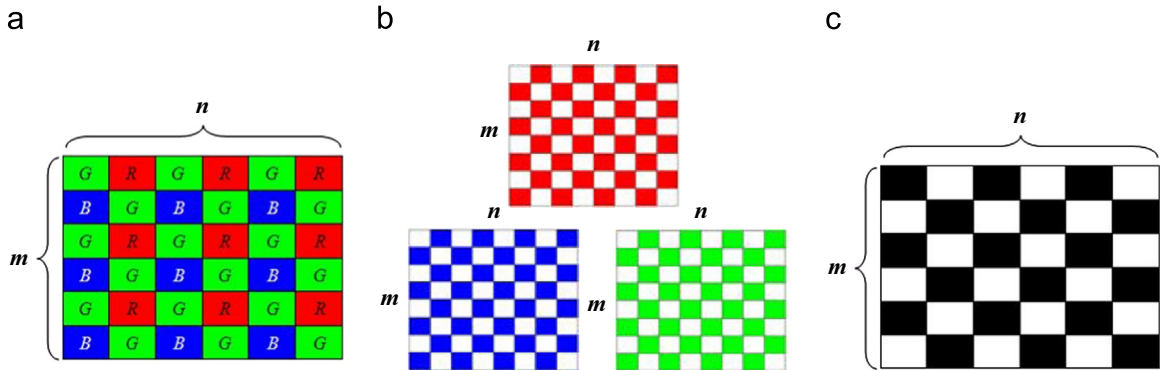


Fig. 1. Interleaving image (a) Bayer's CFA matrix, (b) Lukac's interleaved RGB matrix, (c) Yang's interleaved gray matrix.

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