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Reversible steganography using extended image interpolation technique ☆

Jie Hu *, Tianrui Li

School of Information Science and Technology, Southwest Jiaotong University, Chengdu 611756, China

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ABSTRACT

Steganography has become a hot topic in information hiding, and the reversibility technology allows the recovery of the original image without distortion when the embedded secret information is extracted. In this paper, a high payload image steganographic scheme based on an extended interpolating method is proposed. In the premise of image quality assurance, the proposed scheme increases the capacity by maximizing the difference between neighboring pixels. Meanwhile, it has low complexity and retains good image quality. Extensive experiments on images have been conducted and the experimental results demonstrate that the proposed approach performs better than several state-of-the-art methods.

1. Introduction

Information hiding is a significant information security technology [1]. There are three major research aspects in an information hiding system: security, robustness and capacity. Steganography, the study of techniques for hiding the existence of a secondary message in the presence of a primary message, has become an important branch of information hiding. More and more researchers have devoted to the study of steganographic methods in order to protect secret information in the past 10 years.

With the development of computer network technology and image processing technology, digital images are extensively used online in our daily life. Due to their format redundancy, a large number of digital images have been widely used in information hiding systems. The capacities (or embedding rates) are the number of secret messages embedded in each pixel of cover images [2,3]. The least significant bit (LSB) of pixel values is a popular technique used in the spatial domain because of its direct and simple operation. Now, many reversible steganographic algorithms have been proposed [4–16].

Using the difference expansion of a generalized integer transform, Alattar presented a reversible watermark method with a very high capacity [4]. Celik et al. proposed a novel lossless and reversible information hiding method which may recover the reliable data of original image when extracting the embedded secret information [5]. Ni et al. showed a new reversible information hiding algorithm which can regain the original images from the stego images without any distortion after the hidden secret information had been extracted [6]. Weng et al. introduced a novel reversible information hiding algorithm using an improved difference expansion method (DE) [7]. Jung et al. applied the image interpolation to information hiding method which gained high capacity and good image quality [8]. Using the interpolation-error, e.g., the difference between

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* Corresponding author.
E-mail addresses: jiehu@swjtu.edu.cn (J. Hu), trli@swjtu.edu.cn (T. Li).

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interpolation value and corresponding pixel value, Luo et al. proposed a reversible image watermarking method [9]. Lee et al. designed an efficient image interpolation for information hiding in order to increase the payload (INP) [10]. To diminish the image distortion of high payload information methods, Ou et al. presented a reversible watermarking based on optional prediction-error histogram modification to improve the watermarked image fidelity (or quality) at high embedding rate [11]. Wang et al. proposed a high quality image information hiding scheme by classifying all the image pixels into wall pixels and non-wall pixels [12]. Pei et al. improved embedding capacity of information hiding by using histogram shifting and adaptive embedding [13]. Unlike existing reversible information hiding methods of spatial-domain images, Qian et al. presented a framework of reversible information hiding in an encrypted JPEG bitstream [14]. With the visual quality being preserved, Wu et al. proposed a novel reversible information hiding algorithm for digital images [15]. Using the minimum rate criterion and optimized histograms modification, Hu et al. designed a pixel prediction method applied to reversible information hiding [16].

The interpolation is an important method in digital image processing, by which a small image is scaled up. Through the different interpolation calculations, the different results are obtained. Furthermore, different image capacity and quality will be obtained after using the different interpolation techniques [17,18]. In recent years, the interpolation methods have been widely applied in medical digital imaging processing [19]. The medical digital imaging requires a large amount of data to store patient diagnosis information. Hence, it is meaningful to design interpolation techniques to recover original image better while maintaining high capacity. Jung and Yoo showed the use of image interpolation in the spatial domain of data hiding by Neighbor Mean Interpolation (NMI) [8,10]. Lee and Huang presented an image information hiding method using Interpolation by Neighboring Pixels (INP) [10] which outperformed the [8]. The experimental results showed that the INP had high capacity (up to 2.28 bpp). Therefore, it has been widely used in medical digital image processing.

Based on the above analysis, a higher payload reversible steganography using the extended image interpolation, that is, Interpolation by Maximizing the difference values between Neighboring Pixels (IMNP), is proposed in this paper. The rest of the paper is organized as follows. Section 2 introduces the image interpolation technique and information hiding scheme proposed by Jung et al. [8] and Lee et al. [10]. Section 3 describes the proposed information hiding scheme and shows how the embedding capacity in the image interpolating method can be enhanced while preserving good image quality. The experimental results and analysis are outlined in Section 4. Conclusions are finally drawn in Section 5.

2. Theoretical background

The advantages of interpolation method are of high speed and low time complexity. In this section, some classic interpolation algorithms are reviewed, including NMI [8] and INP on maximum difference values [10].

2.1. Neighbor Mean Interpolation (NMI)

Let the original image and scaling-up image be O and C, respectively. The NMI calculates the mean based on the neighboring pixel values, and inserts it into the scaling-up image C as a pixel. The NMI is calculated as follows: for a 3×3 sub-block, $C(0,0) = O(0,0), C(0,1) = (O(0,0) + O(0,2))/2, C(1,0) = (O(0,0) + O(2,0))/2$ and $C(1,1) = (C(1,0) + C(0,1) + O(1,1))/3$. The NMI can embed a large amount of secret information while keeping good image quality. The experimental results of NMI show that the average stego image quality is 24.44 (dB) measured by peak signal-to-noise ratio (PSNR), which is better than the similar algorithms proposed before. Meanwhile, the NMI method has the advantages of high speed and low-time complexity. Therefore, the NMI is suitable for application of interpolation calculation with a large number of images.

2.2. Interpolation by Neighboring Pixels (INP) on maximum difference values

Firstly, the INP method changes a $M \times N$ size input image I down to 1/4 of itself, and makes it as an original image O. Secondly, the INP uses an interpolation method to enlarge O to form a $M \times N$ cover image C. And then, a $M \times N$ stego image S comes into being from the cover image C after embedding secret information. The receiver can recover the original image O after the embedded secret information is extracted from the stego image S. Please refer to [10] for the more detailed description of embedding and extracting procedures.

In order to improve the embedding capacity, we design a novel image interpolating technique based on INP [10], where a cover image C is produced by an extended image interpolating technique. So the performance of this method is closely related to that of the extended image interpolation technique. The method increases embedding capacity largely by changing the difference between adjacent pixels. The embedding and extracting procedures are described in detail in Section 3.

3. Interpolation by Maximizing the difference values between Neighboring Pixels (IMNP)

Let I be an input image sized $M \times N$. I is resized to be an original image O whose size is 1/4 of I. The proposed IMNP method makes full use of similar properties of adjacent pixels in the original image O to produce a $M \times N$ cover image C. After embedding the secret information into the cover image C, a stego image S is formed. Let the $O(x,y)$ denote a pixel value in (x,y) in the original image O and the $C(x,y)$ describe a pixel value in the pixel location (x,y) of the cover image C. The above course of the cover image C formed in IMNP is described in Eq. (1).