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Low bit-rate information hiding method based on search-order-coding technique

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ABSTRACT

Information hiding method with low bit rate is important in secure communications. To reduce bit rate we propose a new embedding method in this paper based on SOC (search-order coding) compression technique. Compared to Chang et al.'s scheme in 2004, our scheme completely avoids the transform from SOC coding to OIV (original index values) coding to significantly reduce bit rate. In order to further reduce bit rate, Chang et al. proposed a reversible data hiding scheme using hybrid encoding strategies by introducing the side-match vector quantization (SMVQ) in 2013. But it needed additional 1 bit indicator to distinguish the two statuses to determine OIV is belonged to G1 or G2. This overhead gave a large burden to compression rate and could not reduce the bit rate significantly. In contrast, our scheme completely avoids this indicator. The experimental results show that the proposed method can efficiently reduce the bit rate and have the same embedding capacity compared with Chang et al.'s scheme in 2004 and Chang et al.'s scheme in 2013. Moreover, our proposed scheme can also achieve a better performance in both the embedding capacity and bit rate than other related VQ-based information hiding schemes.

1. Introduction

Information hiding method is an essential branch in secure communications, which aims at embedding large amount of secret information into a cover media such as text, image and video. In the case of images, the pioneer research of information hiding is realized in spatial domain. LSB method refers embedding secret information into the least significant bit (LSB) (Chang and Cheng, 2004) of a pixel. Some other methods like Generalized_LSB (Celik et al., 2005) has also been developed based on LSB method. In 2006, Ni et al. proposed a method to embed secret information into the minimum point and the peak point of histogram (Ni et al., 2006). In 2009, Tai et al. utilized binary-tree structure and histogram shifting to embed secret information (Tai et al., 2009). On the other way, information hiding can also be conducted in transform domain such as DCT, wavelet and VQ domain (Gray, 1984). Basic vector quantization (VQ) (Gray, 1984) is widely used in information hiding because of its simple structure and high compression rate. In addition, there exists further chance to compress the VQ index table by means of SOC (search-order coding) technique (Hsieh and Tsai, 1996) because there exists a very strong correlation in VQ index table. One possibility in VQ-compressed domain is to adjust the arrangement of codewords in the codebook. In 1999, Lin et al. proposed an adjustment method that makes two neighboring codewords to be a pair so as to embed bit "0" or "1" (Lin and Wang, 1999). In 2005, Yang et al. utilized the modified fast correlation VQ (MFCVQ) to embed information (Yang et al., 2005). In 2004, Chang et al. proposed an information hiding method using SOC method (Chang et al., 2004). But the method in Chang et al.'s (2004) degraded SOC coding to OIV coding and resulted in a large increasing of bit rate. In order to further reduce the bit rate, Chang et al. proposed a reversible data hiding scheme using hybrid encoding strategies (Chang et al., 2013) by introducing the side-match vector quantization (SMVQ) in 2013 and Chen and Huang used a hybrid dynamic tree-coding scheme and modified search order coding scheme to re-encode the index table in 2009 (Chen and Huang, 2009). In 2006 and 2009, Sharma et al. proposed two information hiding methods which embedded messages in look-up tables (Sharma and Schweid, 2006, 2009). In 2009, Chang et al. proposed a reversible information hiding method for VQ compressed images based on locally adaptive coding method (Chang et al., 2009a). In order to reduce the bit rate of Chang et al.'s method (Chang et al., 2009a) in 2009, Yang and Lin proposed a reversible VQ information hiding method based on the locally adaptive coding method and the fractal-Hilbert-curve approach (Yang and Lin, 2010). In 2009, Yang and Lin proposed some strategies for developing a reversible information hiding approach based on a VQ index table and referred counts (Yang and Lin, 2009). In 2009, Chang et al. proposed a reversible information hiding method for VQ compressed grayscale images by using joint neighboring coding (JNC) technique (Chang

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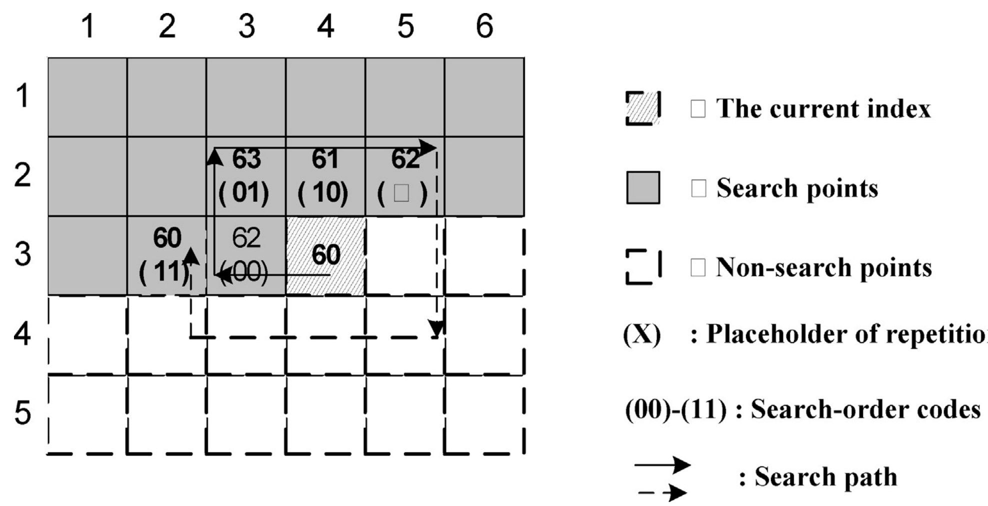

Fig. 1. Flow of SOC method.

et al., 2009b) and Wang and Lu proposed a path optional lossless information hiding scheme based on the joint neighboring coding (JNC) of the VQ index table (Wang and Lu, 2009). In 2010, Shie et al. proposed a visually imperceptible image information hiding scheme based on VQ compression and an adaptive least-significant-bits (LSB) modification technique (Shie et al., 2010). In 2009, Tsai proposed a histogram-based reversible information hiding method for VQ compressed images (Tsai, 2009).

In this paper, we improve the embedding method using SOC technique to realize a significant bit rate reduction and achieve a better performance. The experimental results show that our proposed method can reduce the bit rate and has the same embedding capacity compared with Chang et al.'s schemes (Chang et al., 2004, 2013). Additionally, our proposed scheme has a better performance in both the embedding capacity and bit rate comparing with the other three VQ-based information hiding schemes of Chang et al. (2009a, 2009b) and Yang and Lin (2009).

The rest of this paper is organized as follows. In Section 2, the search order coding method (SOC), the information hiding using SOC technique in Chang et al.'s scheme (Chang et al., 2004) and the information hiding using hybrid encoding strategies in Chang et al.'s scheme (Chang et al., 2013) are presented. In Section 3, the proposed information hiding scheme is given in detail. In Section 4, the experimental results are given and the conclusions are reached finally in Section 5.

2. Related work

2.1. SOC (search-order coding)

VQ (vector quantization) (Gray, 1984) is a kind of lossy data compression method. It is widely used in image processing and speech signal processing. VQ looks for the best match codeword (winner codeword) $\boldsymbol{y}_w = (y_{w0}, y_{w1}, \ldots, y_{w(k-1)})^T$ of the input vector $\boldsymbol{x} = (x_0, x_1, \ldots, x_{k-1})^T$ in the given codebook $C = \{y_i \in R^k, i = 0, 1, \ldots, N-1\}$, which consists of N k-dimensional codewords $y_i = (y_{i0}, y_{i1}, \ldots, y_{i(k-1)})$ $(i = 0, 1, \ldots, N-1)$, where the subscript "i" is the index of the codeword y_i. The measure of the best match for x is defined by

$$d(x, y_i) = \sqrt{\sum_{j=0}^{k-1} (x_j - y_{ij})^2} \tag{1}$$

Therefore the best match codeword is

$$d(\boldsymbol{x}, \boldsymbol{y}_w) = \min_{y_i \in C} [d(x, y_i)] \tag{2}$$

where $\boldsymbol{y}_w$ is the best match codeword and "w" is the index to be transmitted.

Take an image for instance, we first divide the image into a series non-overlapping $n \times n$ blocks. Then each block will be encoded and compressed into one index using a pre-constructed codebook. The index corresponds to the position of a codeword in codebook. After VQ, the encoded image is mapped into an index table (Hsieh and Tsai, 1996). This index table has a strong correlation because the blocks in original image are strongly correlated, which provides the chance of further data compression.

In 1996, Hsieh and Tsai proposed the SOC method for index table. The search path points to the indices which are to be encoded around the current index. The search path goes from center of the current index to its neighbors. If one index in the search path equals to the current index, the current index can be encoded with a shorter code by the search-order coding. Otherwise, continue moving to check indices in the following search path. Specifically speaking, if the index occurs repetitively in search path, put X as a placeholder. The search-order coding is determined by the permitted coding length n. This means that only 2^n different indices can be found by SOC method to encode the current index with n bits. This can reduce the bit rate because n is always less than $\lceil \log_2 N \rceil$. If there is not the same index of the current index, the current index is finally encoded by its binary representation of $\lceil \log_2 N \rceil$ bits. Clearly, the shorter coding by search-order coding technique results in the reduction of bit rate compared to directly using the index itself. Hsieh and Tsai demonstrated that the SOC method achieved 40% compression ratio averagely, which is a large reduction for the amount of code stream.

Fig. 1 shows an example of the SOC method. In this example, assume the permitted coding length n equals to 2. The current index is 60 at the position (3, 4) and a predefined search path is shown with arrows. The block (3, 3) is encoded as "00" because it is the first point which is checked in the search path. Similarly, the block (2, 3) is encoded as "01" because it is the second point which is checked in the search path. Then the block (2, 4) is encoded as "10". The block (2, 5) is not used because it is the same as the index of block (3, 3) and it is marked by "X". The block (3, 2) is encoded as "11" because it is the fourth point checked in the search path. As the index of fourth point (3, 2) equals to the current index, the current index is encoded as "11" in SOC method.