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A Prototypical High-Capacity Data Hiding Based Image Compression Using SMVQ With An Adaptive Index And Block Truncation Coding

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Abstract: The rapid development of the Internet and multimedia technology has caused the hiding and compression of data in digital media to attract increasing attention. Data-hiding based on side match vector quantization (SMVQ) has very low hiding capacity. Since, at most, only one secret bit is hidden in one index code. To overcome this drawback and increase the capacity, the proposed method uses SMVQ with adaptive index and Block truncation coding (BTC). This scheme has an overall satisfactory performance for hiding capacity, compression ratio and decompression quality. Objectives measures were used to evaluate the image quality such as: Compression ratio (CR), Peak Signal to Noise Ratio (PSNR), Bit Rate (BR) and Structural Similarity Index (SSIM).The weighted squared Euclidean distance (WSED) can also be used to increase the probability of SMVQ to get greater hiding capacity. Together the functions of data hiding and image compression can be integrated together into one single module.

Key words: Data Hiding · Image compression · Side Match Vector Quantization (SMVQ) · Block Truncation coding (BTC)

INTRODUCTION

The Internet has become a popular channel for transmitting various data in digital form. The Internet provides abundance of data that is necessary to modern life and accessing the Internet has become part of many people’s daily life. However, two serious problems can occur with Internet communication. The first problem is secrecy, as some data, such as government documents, military photos, commercial contracts and personal medical records, are private. The second problem is related to the flow of large transmissions. Huge documents are transmitted over the Internet every moment, which can overload the Internet and impede transmission.

A fast and safe transfer of secret data should combine compression and protection. Due to the prevalence of digital images on the Internet, how to compress images and hide secret data into the compressed images efficiently deserves in-depth study [1, 2]. Recently, some studies have combined the advantages of data-hiding and compression. Many data-hiding schemes for the compressed codes have been reported, which can be applied to various compression techniques of digital images, such as JPEG, JPEG2000 and vector quantization (VQ) [3, 4].

As one of the most popular lossy data compression algorithms, VQ is widely used for digital image compression due to its simplicity and cost effectiveness in implementation as shown in Figure 2. During the VQ compression process, the Euclidean distance is utilized to evaluate the similarity between each image block and the codeword’s in the codebook. The index of the codeword with the smallest distance is recorded to represent the block. Thus, an index table consisting of the index values for all the blocks is generated as the VQ compression codes. Instead of pixel values, only the index values are stored, therefore, the compression is achieved effectively. The VQ decompression process can be implemented easily and efficiently because only a simple table lookup operation is required for each received index.

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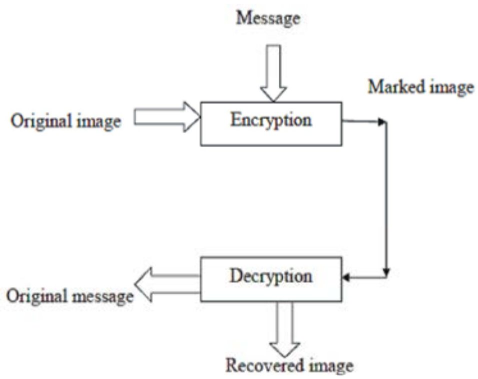


Fig. 1: Reversible Data Hiding

Reversible data embedding for VQ-indexes based on locally adaptive coding [5]. The original VQ coding is completely restored after the extraction of embedded data and encodes the high frequent words with short codes. VQ applications in steganographic data hiding upon multimedia images [6]. In this paper, we classify VQ-based data-hiding methods into four non overlapping groups according to their reversibility and output formats, introduce the details of the representative methods, summarize the features of the representative methods, and compare the performance of the representative methods using peak signal-to-noise ratio, capacity of secret data, and bit rate.

A reversible and high-payload image steganographic scheme implemented in the SMVQ compression domain of image is proposed [7]. This scheme focuses both on the payload of the compressed cover image at the transmitter and on the visual quality of the restored cover image at the receiver. In addition, keeping an acceptable bit rate for the cover image is another goal of this scheme.

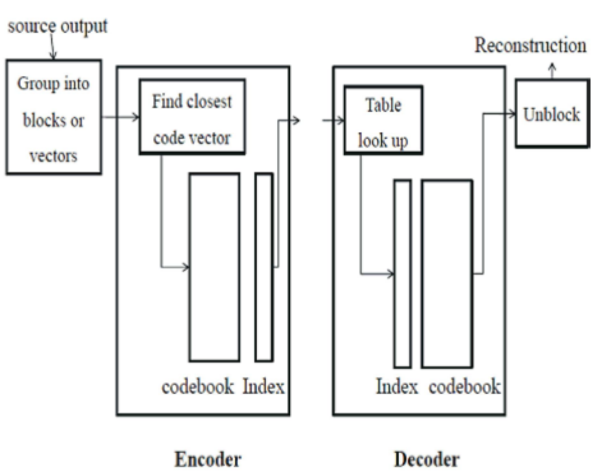


Fig. 2: Vector Quantization

Paper Formulation: Side match vector quantization (SMVQ) was designed as an improved version of VQ, in which both the codebook and the sub codebooks are used to generate the index values, excluding the blocks in the leftmost column and the topmost row which is shown in Figure 3. The weighted squared Euclidean distance (WSED) was utilized to increase the probability of SMVQ for a high embedding rate. In order to make the secret data imperceptible to the interceptors, Shie and Jiang hided secret data into the SMVQ compressed codes of the image by using a partially sorted codebook.

However, in all of the above mentioned schemes, [8, 9] data hiding is always conducted after image compression, which means the image compression process and the data hiding process are two independent modules on the server or sender side. Under this circumstance, the attacker may have the opportunity to intercept the compressed image without the watermark information embedded and the two independent modules may cause a lower efficiency in applications. Thus, in this work, we not only focus on the high hiding capacity and recovery quality, but also establish a joint data-hiding and Compression (JDHC) concept and integrate the data hiding and the image compression into a single module seamlessly, which can avoid the risk of the attack from interceptors and increase the implementation efficiency.

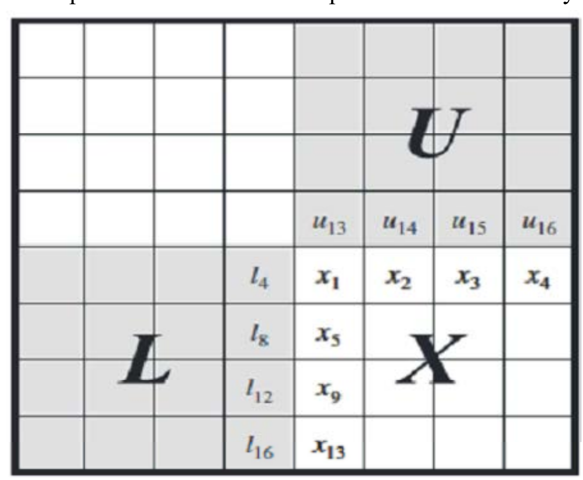


Fig. 3: Side Match Vector Quantization

Proposed Scheme: The image compression in our JDHC proposed scheme is based mainly on the SMVQ and BTC mechanism in which lossless reconstruction of the original image is obtained successfully as shown in Figure 4. The secret data is hidden in compressed codes of the cover image during the encoding process of SMVQ and BTC such that the interceptors will never capture the secret information. Complex blocks are used here to control the visual distortion and error diffusion caused by the progressive compression. It helps provide higher hiding capacity and maintain the size of the encoded image same as that of the original image.

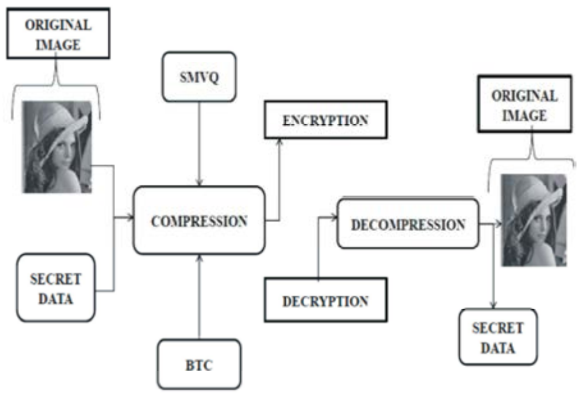


Fig. 4: Joint Data Hiding and Compression(JDHC)

SMVQ Algorithm: Side match vector quantization are a class of FSVQ and tries to make the intensity (grey level) transition across the boundaries of the reproduction vectors as smooth as possible. The assumption behind SMVQ is that the pixel rows and columns of the source image are first-order Markov processes. If the assumption is true, then the pixels contiguous to the current block (the block to be encoded) carry all the information about the current block which is contained in all the past history. In other words, if the pixel rows and columns are first-order Markov, given the pixels that are contiguous to the current block, the current block is conditionally independent of all the rest of the past history. Therefore, ignoring the quantization effect on the past history, the state has to be generated solely by the pixels contiguous to the pixel block to be encoded.

SMVQ Encoding Procedure:

- Encode the first row and the first column of pixel blocks in the image by memory less VQ (e.g., full search VQ) with the super-codebook.

For the rest of blocks, repeat steps 2) and 3).

- Generate the state from the west and north reproduction blocks.
- Encode a block using the quantizer with the corresponding state codebook.

SMVQ Decoding Procedure:

- Decode the first row and the first column of pixel blocks in the image by table-lookup on the super-codebook.

For the rest of blocks, repeat steps 2) and 3).

- Generate the state from the west and north reproduction blocks.
- Decode a block using the de-quantizer with the corresponding state codebook.

Block Truncation Coding: Block Truncation Coding (BTC) is a well-known compression scheme proposed for the grayscale images. It was also called the moment-preserving block truncation because it preserves the first and second moments of each image block. BTC is a recent technique used for compression of monochrome image data. It is one-bit adaptive moment-preserving quantizer that preserves certain statistical moments of small blocks of the input image in the quantized output. The original algorithm of BTC preserves the standard mean and the standard deviation.

The BTC algorithm involves the following steps:

Step 1: The given image is divided into non overlapping rectangular regions. For the sake of simplicity the blocks were let to be square regions of size m x m.

Step 2: For a two level (1 bit) quantizer, the idea is to select two luminance values to represent each pixel in the block. These values are the mean x and standard deviation σ.

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} xi$$

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

where, xi represents the i_{th} pixel value of the image block and n is the total number of pixels in that block.

Step3: The two values x and ó are termed as quantizers of BTC. Taking x as the threshold value a two-level bit plane is obtained by comparing each pixel value xi with the threshold. A binary block, denoted by B, is also used to represent the pixels. We can use “1” to represent a pixel whose gray level is greater than or equal to x and “0” to represent a pixel whose gray level is less than.

$$B = \begin{cases} 1 & x_i \geq \bar{x} \\ 0 & x_i \leq \bar{x} \end{cases}$$

By this process each block is reduced to a bit plane. For example, a block of 4 x 4 pixels will give a 32 bit compressed data, amounting to 2 bit per pixel (bpp).

Step 4: In the decoder an image block is reconstructed by replacing "1□s in the bit plane with H and the "0□s with L, which are given by:

$$H = \bar{x} + \sigma\sqrt{\frac{p}{q}}$$

$$L = \bar{x} - \sigma\sqrt{\frac{p}{q}}$$

Image Quality Measurements: Objective measures were used to evaluate the image quality such as: Peak signal to noise ratio (PSNR) , Compression ratio(CR) and Structural similarity index(SSIM).

Peak Signal to Noise Ratio (PSNR): Peak signal-to-noise ratio (PSNR) is a qualitative measure based on the mean-square-error of the reconstructed image.

$$PSNR = 10 \times \log_{10} \frac{255^2 \times M \times N}{\sum_{x=1}^{M} \sum_{y=1}^{N} [I(x,y) - I_d(x,y)]^2}$$

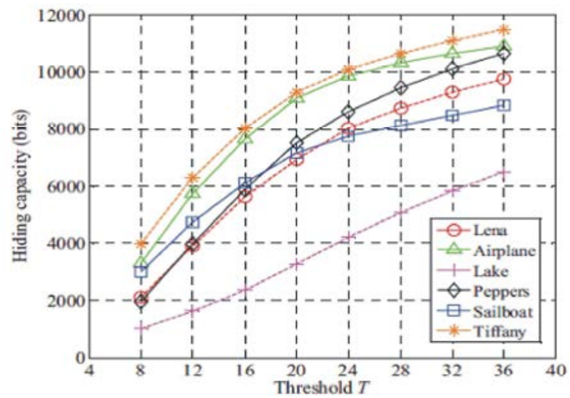
Compression Ratio (CR): Compression ratio is the ratio of the size of original image to the size of the compressed image. Compression efficiency is measured by the compression ratio or by the bit rate.

$$C_R = \frac{8 \times M \times N}{L_c}$$

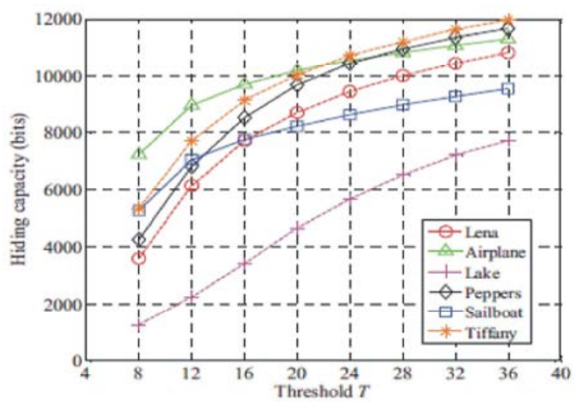
Structural Similarity Index (SSIM): The structural Similarity (SSIM) index can be calculated as a function of three components: luminance, contrast and structure.

$$SSIM(x,y) = [l(x,y)]^{\alpha} . [c(x,y)]^{\beta} . [s(x,y)]^{\gamma}$$

Experimental Analysis: We can observe that, with the same codebook, the hiding capacity increases with the threshold *T* and with the codebook size *W* as shown in Figure 5. The threshold *T* and the JPEG quality factor in were set to 36 and 70, respectively. The hiding capacity of the proposed scheme is equal to the number of residual blocks that satisfy the evaluation condition of SMVQ quality, i.e., distortion value $E_r \leq T$. Furthermore, the proposed scheme can realize data-hiding and image compression simultaneously in a single module, i.e., joint data hiding and compression.



(a)



(b)

Fig. 5: Relationship between hiding capacity and threshold T with codebook size, (a) W=128(b) W=512

Table 1: Comparison of compression performance with Different codebook sizes for LENA image

Schemes	$W = 128$			$W = 256$		
	C_R	PSNR	SSIM	C_R	PSNR	SSIM
VQ	18.29	29.70	0.8871	16.00	30.40	0.9101
SMVQ	20.66	29.70	0.8871	19.80	30.40	0.9100
Scheme in [7]	20.66	28.86	0.8853	19.80	29.75	0.9037
Scheme in [4]	21.98	26.62	0.8754	20.20	28.11	0.8986
Proposed Scheme	20.66	29.85	0.9086	19.80	30.57	0.9353

RESULTS

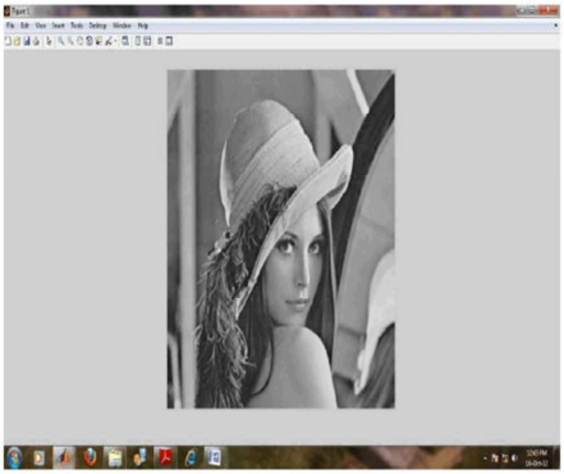


Fig. 6: LENA Input image of size 512×512

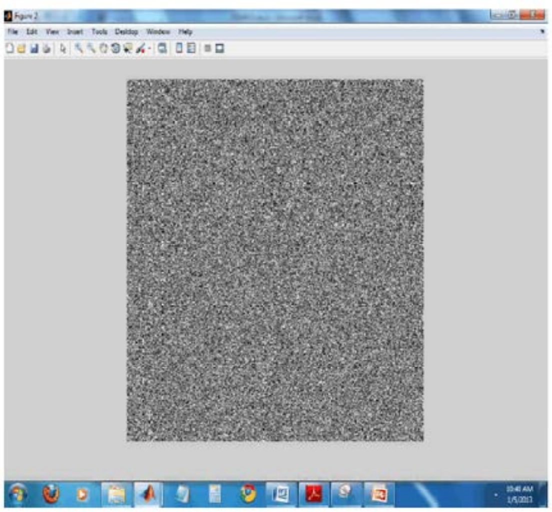


Fig. 7: Encrypted Image with size 512×512

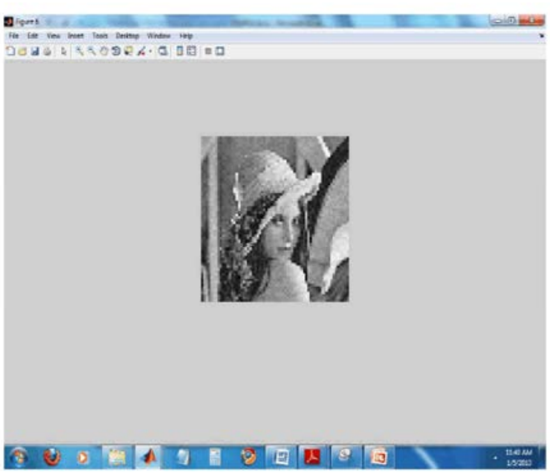


Fig. 8: Reconstructed Image

CONCLUSION

A joint data-hiding and compression scheme based on SMVQ with an adaptive index and Block truncation coding is proposed. On the sender side, except for the blocks in the leftmost and topmost of the image, each of the other residual blocks in raster-scanning order can be embedded with secret data and compressed simultaneously by SMVQ or Block truncation adaptively according to the current embedding bit. After receiving the compressed codes, the receiver can segment the compressed codes into a series of sections by the indicator bits. According to the index values in the segmented sections, the embedded secret bits can be extracted correctly and the decompression for each block can be achieved successfully by VQ, SMVQ and BTC. Ours is an adaptive data hiding method with which one can adjust capacity factor to balance between the image quality and the embedding capacity dynamically.

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