A Modified JPEG-LS Image Compression Scheme for Low Bit-Rate Application

Chien-Wen Chen, Shi-Huang Chen, Tsung-Ching Lin, and Trieu-Kien Truong, *Fellow, IEEE*

***Abstract*—An image compression algorithm using JPEG-LS and cubic spline interpolation (CSI) is presented in this paper. The CSI is developed in order to subsample image data with minimal distortion and to achieve image compression. It has been shown in literatures that the CSI can be combined with the transform-based image compression algorithm to develop a modified image compression codec. The compression ratio obtained from the modified codec is higher than which obtained from the standard transform-based codec at similar subjective quality of reconstructed image. This paper proposes a compression scheme which combines the CSI and JPEG-LS to form the modified JPEG-LS codec and further makes use of this modified codec to image compression. Experimental results show that the compression ratio of proposed scheme has been increased over 3 times higher than the compression ratio of original JPEG-LS image compression standard with similar visual quality. The proposed scheme reduces the loading of storing and transmission of image.**

***Index Terms*—Cubic Spline Interpolation (CSI), Image Compression Codec, JPEG-LS.**

I. Introduction

In the age of digital information, the picture archiving and communications system (PACS) has been accepted by many organizations. PACS is now considered as an essential image management and productivity enhancement tool. The image data compression is used to reduce the storage requirement of a fixed memory system and decrease the time needed for transferring image data between different communication lines or networks. Therefore, by using image compression techniques, the performance of PACS could be further increased by reducing the cost in image transmission and storage [1], [8].

The interpolation function is one of the most important functions used in image data compression. It is the image data processing to estimate the intermediate values from discrete sampling points. It is well known that several interpolation functions such as the linear interpolation [11], the cubic convolution interpolation [3] and the B-spline interpolation [6], etc. can be used in the image compression process. In 1981, Reed [7] developed a linear spline interpolation scheme for re-sampling the discrete image data. This linear spline interpolation is based on the least squares method with the linear interpolation function. Using the ideas of the Reed in [7] and [4], a modified linear spline interpolation algorithm, called the cubic spline interpolation (CSI) algorithm, is developed in [2] for the sub-sampling of discrete image data. The cubic spline interpolation is composed of the least squares method and a cubic convolution interpolation (CCI) formula [5]. The advantage of this scheme over other techniques is that it can be developed to have a very close fit to the original continuous function.

It follows from [2] and [9] that the CSI scheme is superior in performance to the other existing interpolation algorithms. It also has been shown that the CSI can be cooperated with standard image coding systems, e.g. JPEG [10], JPEG-LS and MPEG-4, to obtain the modified image codec, while still maintaining good quality of the reconstructed image for higher compression ratios.

In this paper, the modified JPEG-LS codec with CSI algorithm is constructed and applied to image compression. By comparing with the JPEG-LS image compression standard, experimental results show that the compression ratio of proposed scheme has been increased over 3 times higher than which of original JPEG-LS image compression standard with similar visual quality**.** This algorithm reduces the loading of telecommunication networks and is quite suitable for low bit-rate telecommunication applications.

The remainder of this paper is organized as follows. Section 2 gives the algorithm of the two-dimensional (2-D) cubic spline interpolation. The detail description of the proposed modified JPEG-LS image compression scheme is given in Section 3. Various experimental results are presented in Section 4. Finally, Section 5 concludes the paper.

II. The Algorithm of 2D CSI

The CSI algorithm is designed to recalculate the sampled values of the signal or image data by means of the least-squares method using the cubic convolution interpolation (CCI) formula. For simplification, only two-dimensional (2-D) CSI encoding and decoding algorithms will be briefly described in this section. For more information, see [2].

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Chien-Wen Chen is with the Department of Information Engineering, I-Shou University, Kaohsiung County, Taiwan, 840, R.O.C. (phone:886-7-6577292; fax: 6577293; e-mail: bobchen@isu.edu.tw).

Shi-Huang Chen is with the Department of Computer Science & Information Engineering, Shu-Te University, Kaohsiung County, Taiwan 824, R.O.C. (e-mail: shchen@mail.stu.edu.tw).

Tsung-Ching Lin is with the Department of Information Engineering, I-Shou University, Kaohsiung County, Taiwan, 840, R.O.C. (e-mail: joe@isu.edu.tw).

Trieu-Kien Truong is with the Department of Information Engineering, I-Shou University, Kaohsiung County, Taiwan, 840, R.O.C. (e-mail: truong@isu.edu.tw)

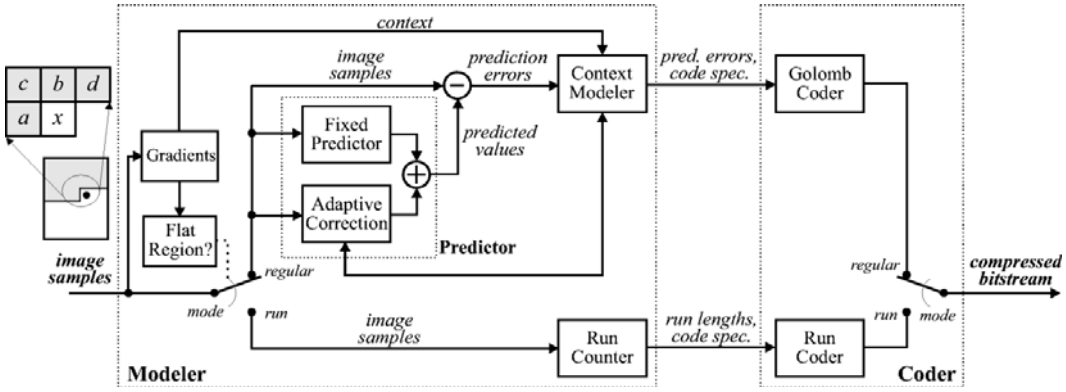


Fig. 1 The block diagram of JPEG-LS

A. Encoding algorithm of the CSI

Let τ be a fixed positive integer. Also, let $X(t_1,t_2)$ be a doubly periodic signal of periods $n_1\tau$ and $n_2\tau$ with respect to the integer variables t_1 and t_2, where n_1 and n_2 are integers. The 2-D CCI function, $R(t_1,t_2)$, is defined by $R(t_1,t_2)=R(t_1)\cdot R(t_2)$, where $R(t_1)$ and $R(t_2)$ are 1-D CCI functions, respectively. The definition of 1-D CCI function, namely $R(t)$, is given as

$$R(t)=\begin{cases}\frac{3}{2}|t|^3-\frac{5}{2}|t|^2+1 & ,0\le|t|<1\\ -\frac{1}{2}|t|^3+\frac{5}{2}|t|^2-4|t|+2 & ,1\le|t|<2\\ 0 & ,2\le|t|\end{cases} \tag{1}$$

The 2-D interpolation can be accomplished by the use of 1-D interpolations with respect to each coordinate. One can define the shift function of the CCI function $R(t_1,t_2)$ as $\Psi_{k_1,k_2}(t_1,t_2)=R(t_1-k_1\tau,t_2-k_2\tau)=R(t_1-k_1\tau)\cdot R(t_2-k_2\tau)$ for $0\le k_1\le n_1-1$ and $0\le k_2\le n_2-1$. By a procedure similar to that used in the 1-D case, the 2-D CSI is defined as

$$S(t_1,t_2)=\sum_{k_1=0}^{n_1-1}\sum_{k_2=0}^{n_2-1}X_{k_1,k_2}\Psi_{k_1,k_2}(t_1,t_2), \tag{2}$$

where X_{k_1,k_2} are the reconstructed values at sampling points which represent the compressed image to be transmitted or stored. Using the fast Fourier transform (FFT), the X_{k_1,k_2} in (2) can be obtained.

B. Decoding algorithm of the CSI

Since the reconstruction values X_{k_1,k_2} for $0\le k_1\le n_1-1$, $0\le k_2\le n_2-1$ are known, the 2-D reconstructed image $S(t_1,t_2)$ is obtained by the use of (2). In other words, the retrieved image is the 2-D convolution of the 2-D CCI function $R(t_1,t_2)=R(t_1)\cdot R(t_2)$ and the 2-D sampled waveform X_{k_1,k_2}.

A simpler method called bilinear interpolation also can be used to perform the 2-D interpolation. The discrete data of each row can be interpolated from the reconstructed values X_{k_1,k_2} with a similar interpolation for the given discrete data of each column. However, by (2) it is easier to obtain the reconstructed image $S(t_1,t_2)$ between the four adjacent reconstructed values by the relations

$$S(t_i,t_j)=\sum_{m=-1}^{2}\sum_{n=-1}^{2}X_{k_1+m,k_2+n}\Psi_{k_1+m,k_2+n}(t_i,t_j) \tag{3}$$

for $k_1\tau<t_i<(k_1+1)\tau$, $k_2\tau<t_j<(k_2+1)\tau$, where the boundary conditions X_{-1,k_2}, X_{n,k_2}, $X_{k_1,-1}$, $X_{k_1,n}$, $X_{-1,-1}$, $X_{n,-1}$, $X_{-1,n}$, and $X_{n,n}$ are given.

III. The Proposed Modified JPEG-LS Codec

In this section, a simple modified JPEG-LS scheme with the CSI is presented. After a serial of modification and improvement, JPEG-LS had become a near lossless to lossless image compression standard in 1999 [12]. With the Low Complexity Lossless Compression for Images (LOCO-I) algorithm embedded, JPEG-LS gains better compression ratio then JPEG and JPEG2000 in lossless domain [13]. Further more, JPEG-LS bridges the compression gap between simplicity-driven schemes, and the more complex ones [14]. The block diagram of JPEG-LS is shown in Figure 1 [13]. In this paper, we combine the low complexity JPEG-LS standard codec with CSI to obtain a modified JPEG-LS algorithm. Using this modified JPEG-LS encoder/decoder for image data compression, the compression ratio of a image can be improved and also the qualities of reconstructed image will be close to the original image.

Figure 2 is the block diagram of the proposed modified JPEG-LS image compression scheme. There are two steps in this modified JPEG-LS encoder. The first step is the pre-processing which uses the CSI scheme for the image.

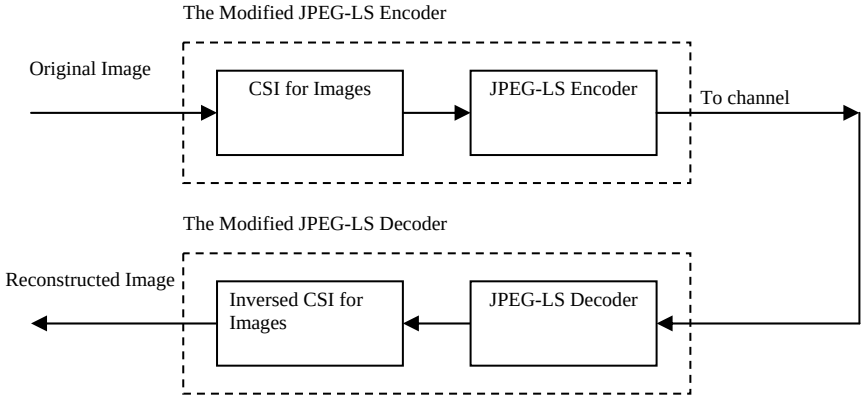
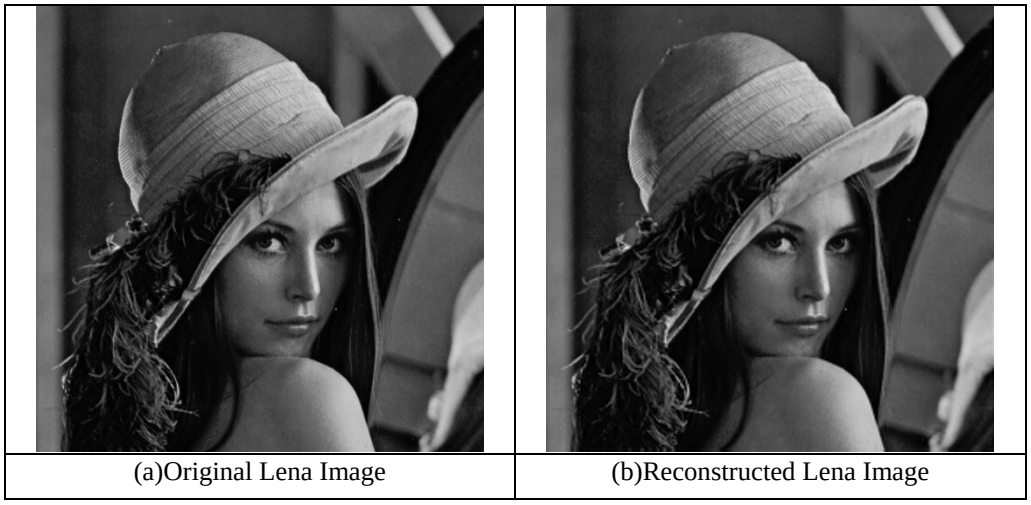
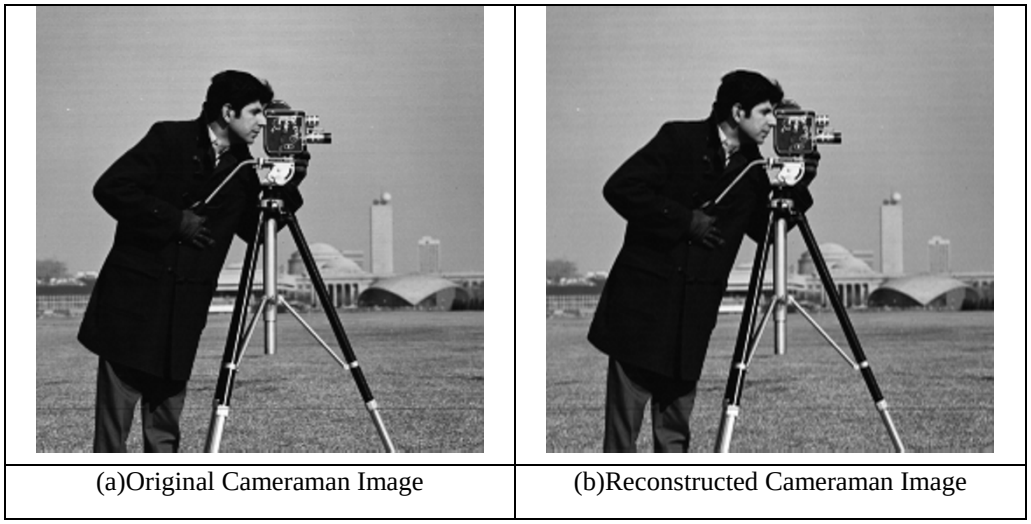


Fig. 2 The modified JPEG-LS codec



(a)Original Lena Image (b)Reconstructed Lena Image

Fig. 3 An example compression result of the Lena image. (a) The 512×512 original gray-level Lena image, and (b) the reconstructed image with a compression ratio 6.847:1 by the modified JPEG-LS codec.



(a)Original Cameraman Image (b)Reconstructed Cameraman Image

Fig. 4 An example compression result of the Cameraman image. (a) The 512×512 original gray-level Cameraman image, and (b) the reconstructed image with a compression ratio 7.625:1 by the modified JPEG-LS codec.

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At the end of the CSI computation, the size of input image will be down-sampled to 1/4. The second step is to use JPEG-LS encoder to compress the down-sampled image and transmit to channel. The modified JPEG-LS decoder is operated in the reverse manner.

Table 1 The Comparison of Compression Ratio

	Lena	Cameraman
Original File Size	262159 bytes	262159 bytes
JPEG-LS	128700 bytes	95287 bytes
CSI+JPEG-LS	38286 bytes	34381 bytes
Compression ratio of JPEG-LS	2.036	2.751
Compression ratio of the proposed scheme	6.847	7.625
PSNR	36.653	38.967
Bit Rate	1.168 bpp	1.049 bpp

IV. Experimental Results

The experimental results are illustrated in this section for the modified JPEG-LS codec that was mentioned in previous section. The original image and the reconstructed image of the Lena are shown in Figure 3, in which where (a) is the original image of the Lena, and (b) is the Lena image reconstructed from the modified JPEG-LS. The compression ratios of the images in (b) are about 6.847:1 respectively. In the comparison of the image quality between those in (a) and (b), one can observe that the images in (a) and (b) are very visually close. Also, Figure 4 shows the original image (a) and the reconstructed result of the Cameraman image by using the modified JPEG-LS. In Figure 4, the compression ratio of the image in (b) is 7.625:1.

The bit-rate and PSNR comparison is given in table 1. One can observe that the compressed Lena and Cameraman image using the proposed method indicates a subjective quality of reconstructed image similar to the original one. This means the modified JPEG-LS with CSI obtains good quality for higher compression ratio of near lossless image compression and is quite suitable for low bit-rate telecommunication applications. For example, for the GPRS-based telecommunication system, the modified scheme can reduce over 3 times of transmission time by the use of the proposed modified JPEG-LS scheme.

V. Conclusion

In this paper, the modified JPEG-LS image compression scheme is proposed for low bit-rate telecommunication applications. By the use of the cubic spline interpolation (CSI), the proposed modified JPEG-LS codec achieves a higher compression ratio and acceptable quality of reconstructed image when comparing with the standard JPEG-LS codec. It follows from experimental results that the compression ratio of proposed modified JPEG-LS scheme has been increased over 3 times higher than which of the standard JPEG-LS data compression codec with similar visual quality. Therefore, the proposed image compression scheme can reduce the upload as well as download time of telecommunication networks. It is also quite suitable for low bit-rate, e.g. GPRS-based, image transmission applications.

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