Lossless Compression Algorithm using Spatial and Temporal Information

Kim, Young Ro* · Chung, Ji Yung**

시간과 공간정보를 이용한 무손실 압축 알고리즘

김 영 로 · 정 지 영

<Abstract>

In this paper, we propose an efficient lossless compression algorithm using spatial and temporal information. The proposed method obtains higher lossless compression of images than other lossless compression techniques. It is divided into two parts, a motion adaptation based predictor part and a residual error coding part. The proposed nonlinear predictor can reduce prediction error by learning from its past prediction errors. The predictor decides the proper selection of the spatial and temporal prediction values according to each past prediction error. The reduced error is coded by existing context coding method. Experimental results show that the proposed algorithm has better performance than those of existing context modeling methods.

Key Words : Adaptive Lossless Compression, Context, Predictor

Ⅰ. Introduction

Many research for lossless compression of digital images are increased. Higher serviced imaging, where images need to be stored in there original undistorted form for future processing, is another important field of application for lossless compression. Also, many high-end digital devices enable the user to access the raw, uncompressed picture, i. e. not altered by any coding algorithm. Many algorithms were proposed. Context-based adaptive prediction schemes[1-5, 7, 8] have shown significant improvements over fixed prediction schemes. CALIC [1] uses gradient adaptive prediction (GAP) and the new lossless compression standard JPEG-LS [2] adopt median edge detector (MED).

Video is a sequence of highly correlated images which consists of almost temporally invariant backgrounds and objects moving across the frames. A few works have dealt specifically with this additional source of redundancy, promising higher gains with respect to independent lossless coding of each

* 명지전문대학 컴퓨터정보과 부교수
** 명지전문대학 컴퓨터정보과 부교수(교신저자)

individual frame. Extended JPEG-LS algorithm using temporal information has been proposed for lossless compression. Although it is rather effective for very little motion, but it does not perform significantly than JPEG-LS if motion is fast and the moving object is large. Motion compensation is commonly used to model motion of objects between subsequent frames, especially for lossy video coding standards such as MPEG and H.264 [3-5]. However, to accurately model, motion of pixels should be considered. Thus, the size of the encoded residual error with context-based coding could be increased.

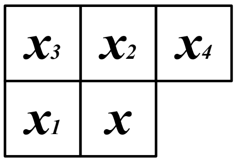
In this paper, we propose a efficient technique called motion adaptive lossless compression algorithm which extends JPEG-LS adding motion adaptive prediction over multiple reference frames to the JPEG-LS framework. Our proposed method achieves good performance for lossless video coding, outperforming existing methods, such as FELICS, CALIC, and JPEG-LS, while having a low complexity.

II. Existing Techniques

In this section, we review the existing context-based coding techniques, such as FELIC, CALIC, and JPEG-LS. Context-based compression methods are constituted by two steps: frist step, the image is spatially de-correlated, then the residual error is determined and second step, entropy according to the context for the residual error is coded.

2.1 Prediction

Prediction is performed based on the causal template as shown in Fig. 1, where x is the current sample, and x_1, x_2, x_3, and x_4, are neighboring samples in the relative positions.



<Fig. 1> Current and neighboring samples

In JPEG-LS [2], a fixed predictor performs a primitive test to detect vertical or horizontal edges, while the other part is limited to an adaptive linear term. The fixed predictor guesses x' of the current sample x as follows

$$x' = \begin{cases} \min(x_1, x_2), & \text{if } x_3 \geq \max(x_1, x_2) \\ \max(x_1, x_2), & \text{if } x_3 \leq \min(x_1, x_2) \\ x_1 + x_2 - x_3, & otherwise. \end{cases} \quad (1)$$

The predictor chooses x_2 as prediction value in cases where a vertical edge exists left of the current position, x_1 in cases of an horizontal edge above the current position, or $x_1 + x_2 - x_3$ if no edge is detected. Because it is seen as the median, this predictor was renamed median edge detector (MED).

In CALIC [1], gradient-adjusted predictor (GAP) guesses x' by adapting itself to the intensity gradient near the predicted pixel. Hence, it has better performance than traditional linear prediction. But, it has more operation than that of MED because of using more boundary pixels.

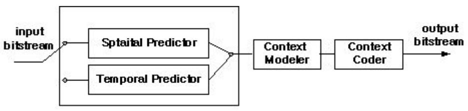
2.2 Context Modeling and Coding

The context is built out of the differences which represent the local gradient[1, 2]. Thus capturing the level of activity surrounding a sample and shows the statistical behavior of prediction errors.

Residual errors after prediction are coded by Huffman or Golomb coding methods. Golomb codes is optimal codes without stored code tables. The case of Golomb codes [6] with 2^k lead to simple coding procedures.

Ⅲ. Proposed Technique

In this section, we proposed a motion adaptive lossless compression algorithm. It has a new predictor which reduce redundancy more than those of existing predictors. Thus, these residual errors of prediction result in higher compression ratio. In Fig. 2, we give a block diagram of the proposed encoder. Decoding is the reverse process.



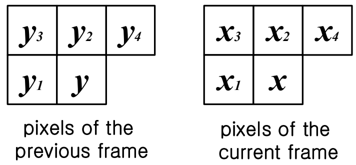
<Fig. 2> Block diagram of the proposed image coding system

In this work, we introduce a new predictor using motion adaptation which takes one of spatial or temporal

informations to coding. Suppose that y is a pixel of the previous frame as show in Fig. 3. In this case, the predicted error using the temporal information is represented by

$$E_x^T = |x - x^T|. \tag{2}$$

where x^T is the temporal predicted value given by y.



<Fig. 3> Samples of current and previous frames

In similar fashion, the predicted error using the spatial information is given by

$$E_x^S = |x - x^S|, \tag{3}$$

where x^S is the guessed value using median edge detector (MED) [2]. In this case, x^S can be replaced by value using any other better spatial predictor. We decide the proper selection of the spatial and temporal prediction values, adaptively as follows

$$x' = x^S \quad \text{if} \sum_{i=1}^{4} E_{x_i}^S \le \sum_{i=1}^{4} E_{x_i}^T$$
$$x' = x^T \quad otherwise \tag{4}$$

where $E_{x_i}^S$ and $E_{x_i}^T$ are the predicted errors of boundary pixels, $x_1, x_2, x_3, \text{and } x_4$, respectively.

For a useful comparison between the proposed and existing methods, context modeling and coding programs are same except for the predictor. We use a Rice-Golomb coder in JPEG-LS [2]. In this case, any other better context modeler and coder can be used with our proposed motion adaptive predictor.

Ⅳ. Experimental Results

For evaluating the proposed scheme, we

implemented the motion adaptive predictor and context coder. In our simulations, the "Football", "Tabletennis", and "Mobile" sequences with 10 frames according to SIF format were used. Each sequence has the different motion type as fast, slow, and panning, respectively. And, they have moving objects of different size. Table 1 presents experimental results of the proposed algorithm. For comparison, results of the FELICS, CALIC, and JPEG-LS algorithms are included. It is seen that the average compression ratio of the proposed method is about 10% better than that of JPEG_LS and better than those of the other existing methods for the Football and Mobile sequences. For the proposed algorithm, the sequence which has the small moving object and the big non-moving background produces better performance than the sequence which has the large moving object. They show that the compression ratio of the proposed algorithm is usually better than that of the other existing algorithms.

<Table1> Comparison of average compression ratio for test sequences

	Football	Tabletennis	Mobile
FELICS	1.44	1.48	1.17
CALIC	1.51	1.58	1.33
JPEG-LS	1.50	1.55	1.32
Proposed method	1.61	3.90	1.55

V. Conclusion

In this paper, a lossless compression technique using the motion adaptive predictor and the context encoder was proposed. The proposed technique efficiently increases the compression ratio by selecting the spatial and temporal prediction values. Experimental results show that the proposed scheme outperforms the existing algorithms such as FELICS, CALIC, and JPEG-LS in terms of the compression ratio while maintaining the same quality as the original image.

참고문헌

[1] X. Wu and N. Memon, "Context-based, adaptive, lossless image coding," IEEE Trans. Communications, vol. 45, no. 4, Apr. 1997, pp. 437-444.

[2] M. J. Weinberger, G. Seroussi, and G. Sapiro, "The LOCO-I Lossless Image Comression Algorithm: Principles and Standardization into JPEG-LS," IEEE Trans. Image Processing, vol. 9, no. 8, Aug. 2000, pp. 1309-1324.

[3] E. Magli, "Optimized onboard lossless and near-lossless compression of hyperspectral data using CALIC," IEEE Geoscience and Remote Sensing Letters, vol. 1, no. 1, Jan. 2004, pp. 21-25.

[4] M. J. Weinberger, J. Rissanen, and R. B. Arps, "Application of universal context modeling to lossless compression of gray-scale images," IEEE Trans. Image Processing, vol. 5, Apr. 1996, pp. 576-586.

[5] X. Wu, "Efficient lossless compression of continuous-tone images via context selection and quantization," IEEE Trans. Image Processing, vol. 6, May 1997, pp. 656-664.

[6] S. W. Golomb, "Run-length encodings," IEEE Trans. Inform. Theory, vol. IT-12, Jul. 1966, pp.

399-401.

[7] P. G. Howard and J. S. Vitter, "Fast and Efficient Lossless Image Compression," in Proc. 1993 Data Compression Conf., Snowbird, UT, Mar. 1993, pp. 351-360.

[8] V. Dai and A. Zakhor, "Lossless Compression of VLSI Layout Image Data," IEEE Trans. on Imag. Processing, vol. 15, no. 9, Sep. 2006, pp. 2522-2530.

■ 저자소개 ■

김 영 로
Kim, Young-Ro

2003년~현재
명지전문대학 컴퓨터정보과 교수
2001년~2003년
삼성전자 시스템LSI책임연구원
2001년 고려대학교 전자공학과 (공학박사)
1996년 고려대학교 전자공학과 (공학석사)
1993년 고려대학교 전자공학과 (공학사)

관심분야 : 신호 및 영상처리, 멀티미디어 통신
E-mail : foryoung@mjc.ac.kr

정 지 영
Chung, Ji Yung

2002년~현재
명지전문대학 컴퓨터정보과 교수
2005년 아주대학교 대학원 (공학박사)
2000년 아주대학교 대학원 (공학석사)
1998년 아주대학교 컴퓨터공학과 (공학사)

관심분야 : 클러스터 시스템, 결함허용 시스템
E-mail : abback@mjc.ac.kr

논문접수일 : 2009년 7월 28일
수 정 일 : 2009년 8월 20일
게재확정일 : 2009년 8월 30일