Motion Adaptive Lossless Image Compression Algorithm

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Abstract   In this paper, an efficient lossless compression algorithm using motion adaptation is proposed. It is divided into two parts: a motion adaptation based nonlinear predictor part and a residual data coding part. The proposed nonlinear predictor can reduce prediction error by learning from its past prediction errors using motion adaption. The predictor decides the proper selection of the intra and inter prediction values according to the past prediction error. The reduced error is coded by existing context adaptive coding method. Experimental results show that the proposed algorithm has the higher compression ratio than context modeling methods, such as FELICS, CALIC, and JPEG-LS

요 약   영상 내의 움직임 적응적인 효과적인 무손실 영상 압축 알고리즘을 제안한다. 이 알고리즘은 비선형 예측기를 토대로 움직임에 적응하는 단계와, 예측기에 의한 차분 데이터를 압축하는 단계로 구성된다. 제안한 비선형 예측기는 과거의 예측 오차로부터 화면간 혹은 화면내 예측치를 선택하며, 움직임 적응 단계를 진행되면서 주변 화소들의 예측 오차를 고려하여, 현재 화소에 대한 예측 오차를 줄이는 능력을 가진다. 예측 오차는 기존의 문맥 적응적인 코딩 기법에 의해서 압축된다. 실험결과는 제안한 알고리즘이 FELICS, CALC, JPEG-LS와 같은 문맥 모델링에 기반을 둔 무손실 압축 기법보다 우수한 압축률을 보여준다.

Key Words : Lossless compression, Motion adaption, Context predictor

1. Introduction

Recently, the demands for lossless compression of digital images are increasing. Higher serviced imaging, where images need to be stored in their undistorted original 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 have been proposed. Context-based adaptive prediction schemes[1-5,7] have shown significant improvements over fixed prediction schemes. CALIC[1] uses gradient adaptive prediction (GAP) and the new lossless compression standard JPEG-LS[2] adopts the 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 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 or 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, it should be considered to accurately model motion of pixels. Thus, the size of the encoded residual error with context-based coding could be increased.

In this paper, we propose an efficient technique called motion adaptive lossless compression algorithm which extends JPEG-LS, which adds 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.

2. Overview of Existing Techniques

2.1 De-correlation

In this section, the existing context-based coding techniques, such as FELIC, CALIC, and JPEG-LS are to be reviewed briefly. The context-based compression methods are composed of two steps. In the first step, the image is spatially de-correlated, and then the residual error is determined. In the second step, the residual error is coded by the context-adaptive entropy encoder.

To de-correlate, the 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 that had been encoded already.

x_3	x_2	x_4
x_1	x	
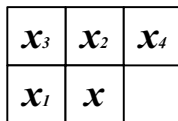
[Fig. 1] Current and neighboring samples

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 is decided as follows

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

The predictor chooses x_2 as prediction value in cases where a vertical edge exists at the 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. This predictor was renamed as the median edge detector (MED), because it looks like the median.

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

2.2 Context modeling and coding

The context is built based on the differences which represent the local gradient[1-2]. Thus the activity surrounding a context shows the statistical behavior of prediction errors.

Residual errors after prediction are coded by Huffman or Golomb context encoder. The Golomb encoder is very effective since no code tables are to be stored. The case of Golomb codes[6] with 2^k lead to a simple coding procedure.

3. Proposed Algorithm

3.1 Motion adaptive lossless compression

In this section, we proposed a motion adaptive lossless compression algorithm. It has a new predictor which can reduce redundancy more than that of existing algorithms. Thus, the residual errors of prediction lead to a higher compression ratio. The block diagram of the proposed encoder is shown in Fig. 2. Decoding is the reverse process.
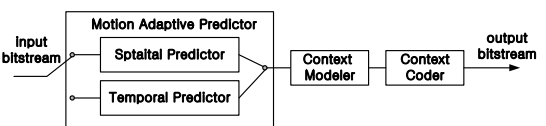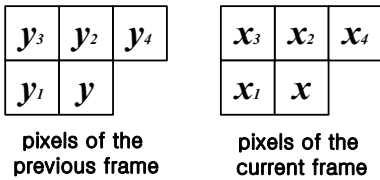

[Fig. 2] Block diagram of the proposed image coding system

In this work, we introduce a new predictor using motion adaptation which takes one of spatial or temporal information to coding. Suppose that y is a pixel of the previous frame as shown in Fig. 3. In this case, the predicted error using the temporal information is represented by

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

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

y_3	y_2	y_4
y_1	y	

x_3	x_2	x_4
x_1	x	

pixels of the previous frame   pixels of the current frame

[Fig. 3] Samples of current and previous frames

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

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

where x^s is the guessed value using median edge detector (MED). We decide the proper selection between the spatial and temporal prediction values, adaptively as follows

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

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

For context coding and a useful comparison between the proposed and existing methods, a Rice-Golomb coder is used[2]. Since the proposed predictor using motion adaptation can reduce the prediction errors more than predictors of existing algorithms, the proposed encoder can have the higher compression ratio.

3.2 Simulation Results

For evaluating the proposed scheme, we implemented the motion adaptive predictor and the context coder. For 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 with the small moving object and the big non-moving background produces better performance than the sequence which has the large moving object. Fig. 4, 5, and 6 show the compression ratio between the existing and the proposed algorithms using several image sequences. They show that the compression ratio of the proposed algorithm is usually better than that of the other existing algorithms.

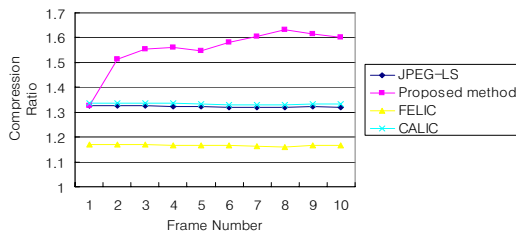[Table 1] Comparisons of average compression ratio for test sequences

	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	1.61	3.90	1.55
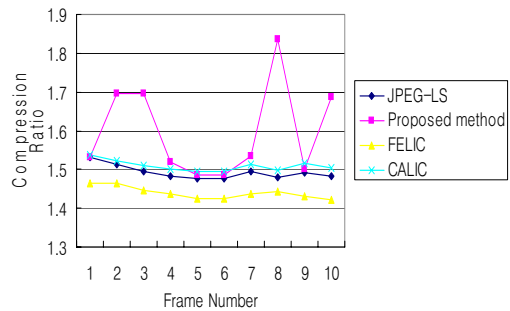
[Fig. 4] Compression ratio per frame for "Football"
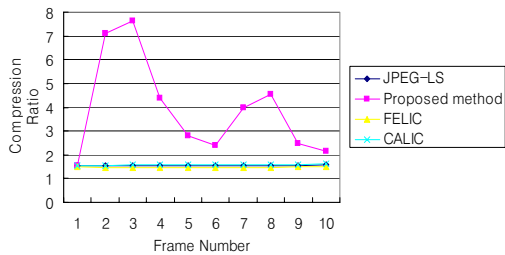
[Fig. 5] Compression ratio per frame for "Tabletennis"

[Fig. 6] Compression ratio per frame for "Mobile"

4. Conclusions

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 adaptively. 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.

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<Research Interests>
Image processing algorithm, image enhancement, lossless compression

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Image signal processor, multi-media SoC architecture